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WEEKLY 23 November 2024

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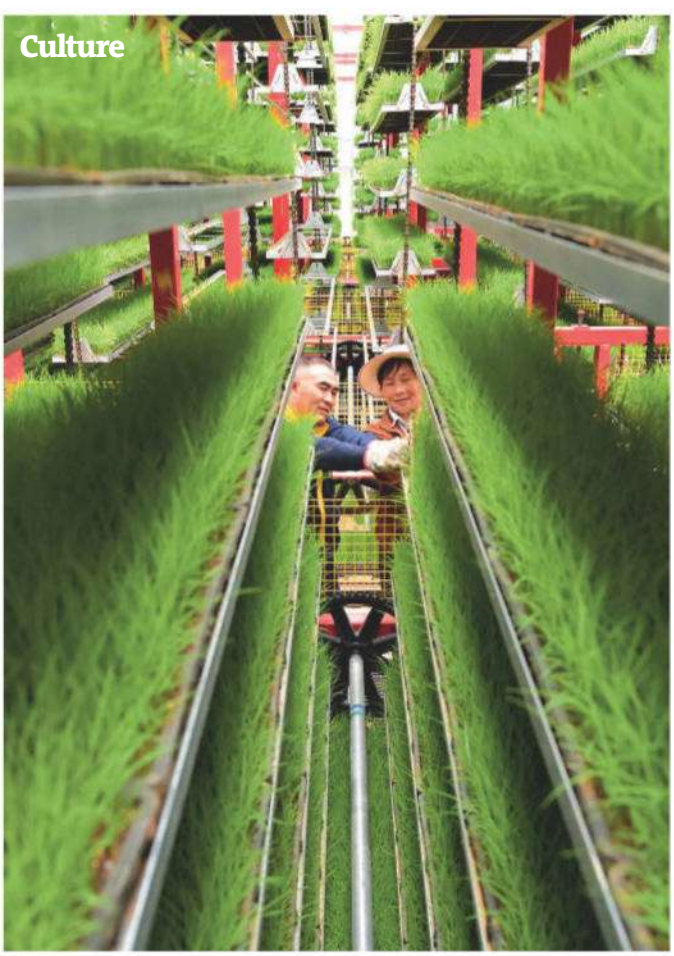

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Mysteries of the mind

What is really going on inside the human brain? Join six pioneering researchers who will illuminate the neural underpinnings of thought, emotion and communication. Gain insights on topics such as the effects of screen time and how we can be happier, and explore strategies to optimise brain performance on 7 December at London's Congress Centre.

newscientist.com/events

Tour

Astronomy in the Canary Islands: Spain

Join astronomy journalist Stuart Clark on an expedition to UNESCO starlight reserve La Palma. Stargaze and visit an array of telescopes here and on the neighbouring island, Tenerife. During the day, you will visit subtropical rainforests, volcanoes and ancient cave petroglyphs. This seven-day tour starts on 27 November 2025 and costs £3289.

newscientist.com/tours

Podcast

Weekly

The team discuss some impressive tales of bird intelligence and look into a study showing the engineering prowess of gophers. Plus, get the lowdown on the COP29 climate summit, which took place in Azerbaijan, a petrostate, shortly after the summit's chief executive was secretly filmed using his role to facilitate oil and gas deals.

newscientist.com/nspod

JOSE A. BERNAT BACETE/GETTY IMAGES

Volcanic stargazing La Palma is Europe's premier dark sky site

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Sound pollution Military submarines alter dolphin pod behaviours

Video

The trouble with sonar

Sound is essential for communication and sensing in dolphins and whales. Conservation company SEA Inc has been tracking how sonar from military submarines and ships affects the behaviour of large groups of these mammals over long distances. Insights into how sonar affects their social dynamics can be used to mitigate harm in the future.

youtube.com/newscientist

Newsletter

Wild Wild Life

We all know that being in nature is good for us, but how does it work its magic? Kathy Willis, former director of science at the Royal Botanic Gardens, Kew, explores this question in her new book *Good Nature*. Find out about the latest research revealing what being in nature does to our brains and bodies.

newscientist.com/wild-wild-life

Newsletter

"Birdsong is best at reducing stress, whereas water sounds improve mood"

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For us, the transition to more sustainable energy isn't as simple as just abandoning fossil fuels, because it's going to take time to increase renewables at the scale required.

Our plan is to constantly keep searching for better. Better technologies, better solutions for reducing and storing emissions, and better ways to produce the energy we supply today, and that the world needs in the future.

And over the last few years, we have accelerated our investments in the energy transition. Last year, 20% of our global gross spend was invested in renewables and lower carbon solutions, such as carbon capture and storage, a process where we capture CO_2 where its emitted, and store it safely and permanently underground. Our ambition is that our investments in profitable renewables and lower carbon solutions will reach 50% of our gross annual expenditure in 2030.

It has been 14 years since the work to develop the world's largest offshore wind farm, Dogger Bank, started. Last year, the first electricity was delivered to households in the UK, and when the entire park of more than 270 turbines is ready, it will supply more than six million British homes with renewable energy.

And until we reach the point where we can leave oil and gas in the ground, we are always searching for better ways to produce it. In 2023, we reduced our operated carbon emissions down to 11.6m tonnes. That's 30% less compared to 2015 levels. By 2030, we aim to turn this into a net reduction of 50%.

We'll never stop searching for solutions to help reduce emissions and ease the dependence on oil and gas. We don't have all the answers yet, but our innovations, technology, and the determination of our people will help get us there. That's why we will always keep searching for better.

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In the hot seat

City mayors can play an important role in coping with climate change

IT HASN'T been a good year for people who care about climate change. A hoped-for peak in carbon emissions has failed to emerge, meaning we continue to warm the planet at an accelerating rate (see page 10). Meanwhile, the election of Donald Trump for a second term as US president is likely to see the country retreat on climate action, with his pledge to "drill, baby, drill" for new oil and gas supplies.

Similar sentiments towards fossil fuels come from Ilham Aliyev, the president of Azerbaijan, who has called the natural resources of his oil-rich nation a "gift from God". Aliyev made the comments at the COP29 climate summit, hosted in Azerbaijan's capital, Baku. Ironically, this "gift" will become increasingly inaccessible as the Caspian Sea dries up in a warming world, stranding billions of dollars of fossil fuel infrastructure (see page 8).

In light of this failure by politicians on the international stage to get to grips with the reality of climate change, other leaders need to step up – and, surprisingly, city mayors may be best placed to do so.

> "Adapting cities to cope with the specific effects of urban heat will be essential"

While mayors can't be expected to influence the global climate, they oversee the well-being of the more than 50 per cent of the world's population who live in urban centres – a figure expected to grow to 70 per cent by 2050, at which point temperatures will have risen by 2.5°C under current projections. Adapting cities to cope with the specific effects of urban heat will be essential, from promoting green spaces to investing in buildings that can be cooled without air conditioning (see page 36).

The good news is many mayors are already aware of their responsibilities. London's mayor, Sadiq Khan, is aiming for the city to reach net zero by 2030. Anne Hidalgo, mayor of Paris, France, has planted trees and banned cars in certain areas. And Karen Bass, mayor of Los Angeles, has promised a green transformation ahead of the city hosting the Olympics in 2028. Organisations like C40 and Climate Mayors are helping unite local politicians across the world in action. This won't solve climate change, but it will make living in a warming world more bearable for many. ▮

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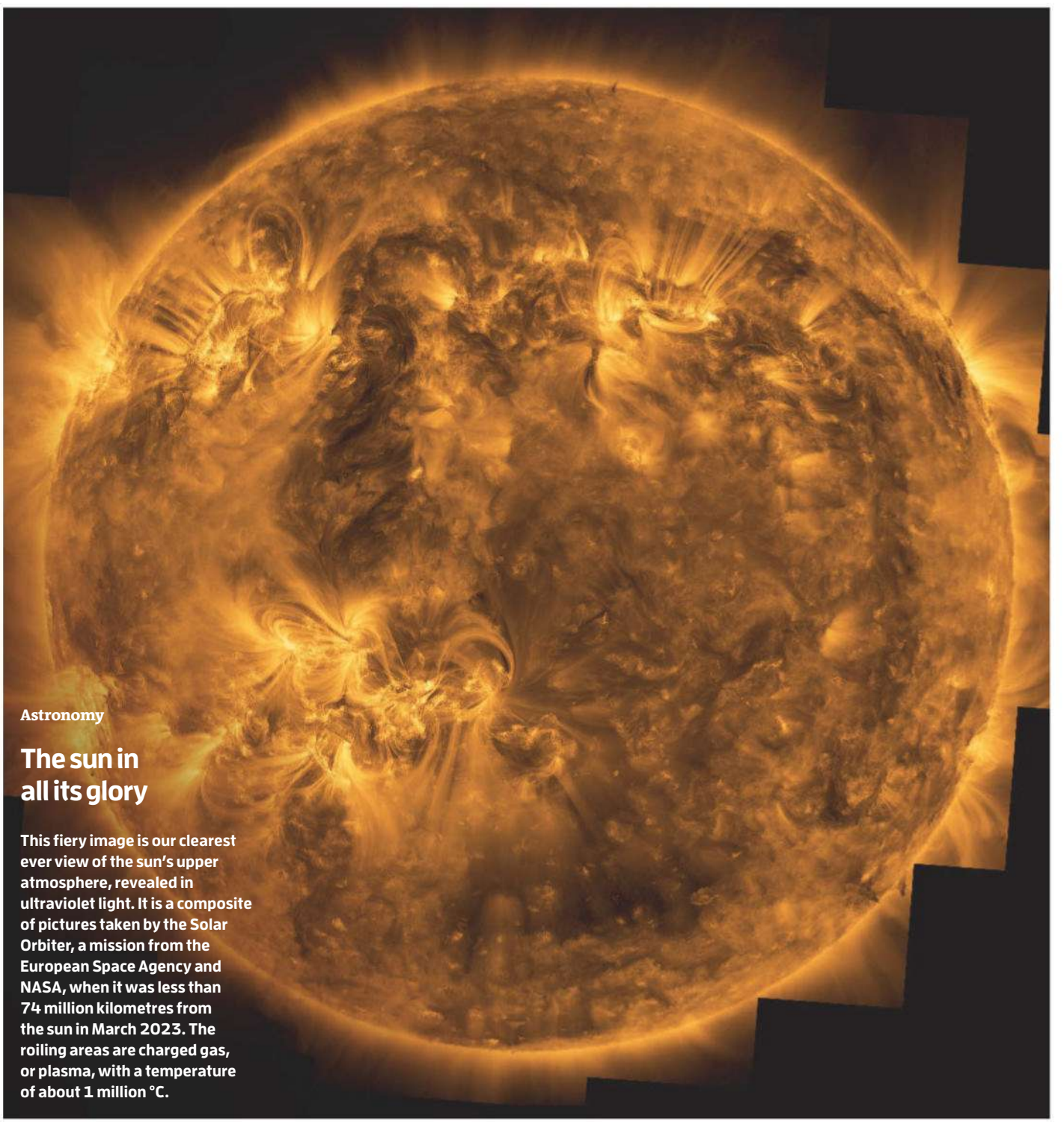


Astronomy

The sun in all its glory

This fiery image is our clearest ever view of the sun's upper atmosphere, revealed in ultraviolet light. It is a composite of pictures taken by the Solar Orbiter, a mission from the European Space Agency and NASA, when it was less than 74 million kilometres from the sun in March 2023. The roiling areas are charged gas, or plasma, with a temperature of about 1 million °C.

ESA & NASA/SOLAR ORBITER/EUI TEAM

Sea level change

COP29 host faces climate disaster

Water levels in the Caspian Sea are set to fall dramatically as the climate gets hotter, threatening economic activity and ecosystems in Azerbaijan, finds **Madeleine Cuff**

PORTS, oil drilling rigs and coastal settlements will be marooned kilometres from the shore as climate change drives water loss in the Caspian Sea, according to a study that highlights the huge economic threat global warming poses to Azerbaijan, the host of the COP29 climate summit.

Water levels are already falling fast in the Caspian Sea, the world's largest inland body of water, in part because Russia is diverting water from the Volga river for agriculture. In 2023, the average level dropped by 30 centimetres compared with the previous year, according to CASPCOM, a local meteorological service.

As global temperatures rise, evaporation rates over the Caspian Sea are expected to increase, accelerating the rate of decline. Modelling suggests sea levels there could drop by 15 metres by the end of the century if there is 2°C of warming. With higher levels of carbon emissions, there could be a fall of up to 21 metres.

"As the world warms, that is going to drive increased evaporation rates," says Simon Goodman at the University of Leeds, UK. "This evaporation rate is outstripping that inflow and accumulation of water within the Caspian Sea."

While this decline in sea level is well established, few studies have looked at the real-world impact of such a dramatic water loss. Goodman and his colleagues used geospatial data to map how a change in water levels across the Caspian Sea would affect key ecological areas and infrastructure.

"Even under the most optimistic scenarios, you're probably looking at something like 9 to 14 metres [of sea level reduction]," says Goodman.

The results suggest that as water levels recede, billions of dollars of economic infrastructure could be at risk across the five nations that border the Caspian Sea: Russia, Iran, Azerbaijan, Turkmenistan and Kazakhstan.

REUTERS/GRIGORY DUKOR

Water loss could leave oil rigs in the Caspian Sea kilometres from the water

Out of 22 industrial infrastructure facilities included in the analysis – including ports, oil refineries and gas processing plants – eight will see their distance to the shoreline increase by more than 5 kilometres if sea levels fall by 10 metres (bioRxiv, doi.org/nspd).

9 to 14m

Fall in Caspian Sea levels by 2100, under optimistic scenarios

5km

Distance industrial infrastructure could be left from the shore

The north-eastern basin of the Caspian Sea is especially shallow and therefore is likely to see the most extreme impacts. It is also home to two of the region's most important fossil fuel production sites, the Kashagan and Filanovsky oil fields, controlled by Kazakhstan and Russia respectively. These extract from offshore rigs, which will become landlocked if sea levels fall by 5 metres or more, the team found.

Already, parts of the seabed have been dredged to allow the offshore oil rigs to continue production. Fishing communities could also become stranded far from the shoreline they depend on, according to the research.

The ecological threat, too, is vast, with the loss of vital habitats for insects, marine life, migratory birds and the Caspian seal (*Pusa caspica*), which is found only in this region. "It is mass habitat loss," says Rebecca Court at the University of Leeds, who also worked on the study.

Goodman stresses that the assessment – which hasn't yet been peer reviewed – is relatively simplistic and doesn't take into account water depth or the response of ecosystems to shifting conditions. "We're cautious about saying this is a crystal ball that is going to foretell an exact kind of future," he says.

Nevertheless, it is clear that a change in water levels of this scale would have devastating consequences, says Kate Watters at environment and human rights group Crude Accountability. "It's a disaster for all of those living and depending on the Caspian Sea for their livelihood."

The COP29 climate summit took place this month in Baku, the capital of Azerbaijan, which lies on the western shore of the Caspian Sea. The country's economy is highly dependent on fossil fuels, which account for 90 per cent of its exports, and its president, Ilham Aliyev, told world leaders at the summit that oil and gas are a "gift from God". The burning of fossil fuels is the primary driver of global climate change.

So far, the COP presidency is doing little to advance discussions on ending global fossil fuel use, says Andreas Sieber at campaign group 350.org, speaking from Baku. At last year's COP summit in Dubai, countries agreed to start "transitioning away" from fossil fuel use, and strengthening this commitment is a key priority for some nations at COP29.

Despite the presidency's reluctance to discuss the topic at COP29, it is in Azerbaijan's long-term interests to reduce its reliance on fossil fuels, says Sieber. The European Union, one of its main customers, has already signalled that it plans to cut its use of natural gas by 30 per cent by the end of the decade.

"It's in the interests of Azerbaijan to diversify their economy," says Sieber. "Anything else seems pretty unwise from an economic point of view." ▮

Emissions plans

Some countries are cheating their way to net zero by overrelying on forests

Madeleine Cuff

NATIONS are taking a shortcut to net-zero emissions by including forests and other "passive" carbon sinks in their climate plans, in a tactic that could thwart global efforts to halt climate change.

Relying on natural carbon sinks to soak up ongoing carbon emissions from human activity will condemn the world to continued warming, say researchers who first developed the science behind net-zero emissions, and who have called out nations and companies for misusing the concept (*Nature*, DOI: 10.1038/s41586-024-08326-8).

"This paper is a call to clarify to people what was originally meant by net zero," Myles Allen at the University of Oxford told a press briefing on 14 November.

Natural sinks such as forests and peat bogs play a vital role in Earth's natural carbon cycle by absorbing some of the carbon in the atmosphere. But if existing sinks are used to offset ongoing greenhouse gas emissions, global atmospheric concentrations of carbon dioxide will remain stable once "net zero" is reached, and warming will continue for centuries because of the way the oceans absorb heat, said Allen. "You could think you are on a path of 1.5°C, and end up with warming of well over 2°C," he said.

To stop global temperatures rising, emissions need to reach net zero without relying on passive uptake by the land and oceans. This allows existing natural sinks to continue absorbing excess CO_2, bringing down atmospheric concentrations of the gas and offsetting ongoing warming from the deep ocean.

However, many countries already count passive land sinks such as forests as greenhouse gas removal in their national carbon accounts. Some, including Bhutan, Gabon and Suriname, have even declared themselves to be already net zero, thanks to their existing extensive forest cover.

Others have set long-term targets based on this approach. Russia, for example, has promised to reach net-zero emissions by 2060, but the plan relies heavily on using its existing forests to absorb ongoing carbon emissions.

"Maybe you will get some countries deliberately using this in a mischievous way," Glen Peters at the CICERO Center for International Climate Research in Oslo, Norway, told the press briefing.

The team fears the issue will become more acute as the pressure on nations to decarbonise intensifies. Natural sinks can count as carbon removal if they are additional, for example, if a new forest is planted, but they are vulnerable to climate impacts such as wildfires so shouldn't be relied on to balance out ongoing emissions, said Allen.

Nations and companies with net-zero targets should exclude passive carbon uptake and aim for "geological net zero", he said, which would ensure that ongoing carbon emissions are balanced with long-term carbon storage underground.

"If you are still generating carbon dioxide from burning fossil fuels by mid-century, you need to have a plan to put the carbon dioxide they generate back into the ground," said Allen. ▮

Some net-zero plans rely on existing forests absorbing emissions

MORLEY READ/ALAMY

Environment

Planet-warming methane leaks aren't getting fixed

COMPANIES and governments rarely take action when alerted to large methane leaks, some of which have the climate-warming effect of hundreds of thousands of cars driven for a year.

Methane is a potent greenhouse gas responsible for a third of global warming so far. A rising number of countries, as well as many of the largest oil and gas companies, have promised to slash these emissions.

Today, a growing number of satellites, as well as ground and aeroplane-based sensors, are helping by detecting methane leaks from their main sources: oil and gas infrastructure, coal mines, landfill and agriculture. The United Nations International Methane Emissions Observatory recently launched a system that uses satellite data to alert methane emitters about leaks.

A report released at the COP29 summit illustrates the yawning gap between measuring methane and doing something about it. Over the past year, the UN system issued 1225 alerts to governments and firms when it identified large plumes of methane detectable from space. The "super-emitters" took steps to control those leaks only 15 times, a response rate of about 1 per cent.

There are a number of possible reasons for this, says the UN observatory's director, Manfredi Caltagirone, including a lack of resources, difficulty stemming certain leaks and the novelty of the UN alert system. But other methane monitors report that their leak alerts have a similarly low response rate.

1%

Rate at which methane emitters respond to alerts of leaks

Despite some successes – such as a decades-old leak in Algeria being shut off after the UN alerted the government – monitoring isn't yet translating into emissions reductions. "Simply showing methane plumes is not enough to generate action," says Rob Jackson at Stanford University, California. ▮

James Dinneen

Emissions

Fossil fuels and forest fires push carbon dioxide emissions to record high

James Woodford and James Dinneen

CARBON dioxide emissions from burning fossil fuels in 2024 are set to blow past last year's record levels, dashing hopes that this year will see the planet-warming emissions peak.

"Reducing emissions is more urgent than ever and there's only one way to do it: massively reduce fossil emissions," says Pierre Friedlingstein at the University of Exeter, UK.

~90%

of the world's emissions come from burning fossil fuels

That is according to the latest Global Carbon Budget report, a preliminary accounting of CO_2 emissions to date with projections to the end of the year, produced by Friedlingstein and his colleagues. It was released at the COP29 climate summit in Azerbaijan.

Last year, some researchers were forecasting a peak in emissions in 2024, but the report finds that human-caused CO_2 emissions are set to reach a record 41.6 gigatonnes in 2024, a 2 per cent rise on 2023's record. Almost 90 per cent of that total consists of emissions from burning fossil fuels. The rest is from changes in the land driven mostly by deforestation and wildfires.

At 0.8 per cent, the growth rate of fossil fuel emissions is half that of 2023, although it remains higher than the average rate over the past decade. "[The slower rate] is a good sign, but it's still miles away from where we need to get," says Friedlingstein.

Despite a long-term downward trend, projected emissions from land use change also increased this year, largely due to drought-driven wildfires in the tropics. Some of the increase is also down to a collapse of the carbon land sink in 2023, which usually removes about a quarter of our annual CO_2 emissions from the atmosphere. This sink declined by more than 40 per cent last year and the early part of 2024 as global temperatures spiked under the influence of El Niño.

"2023 is an incredible demonstration of what can happen in a warmer world when we had peak records in global temperatures combined with El Niño droughts and fires," says Pep Canadell at the Commonwealth Scientific and Industrial Research Organisation in Australia, a co-author of the report. "Put all these things together and last year we had almost a third less help removing atmospheric CO_2 by the world's forests than we have had over the last decade."

CARLOS FABAL/AFP VIA GETTY IMAGES

A mural in Sao Paulo, Brazil, made from ash from forest fires that have hit the country

While this also added to emissions in 2024, the researchers expect this "land carbon sink" has mostly recovered as the warming influence of El Niño has faded.

The report finds that CO_2 emissions in China, which generates nearly a third of the global total, are only projected to increase by 0.2 per cent in 2024 compared with 2023. India's emissions also grew at a slower rate than last year, rising by just under 5 per cent. In the US and the EU, emissions continued to decline, albeit at a slower rate than last year.

Hot temperatures that boost electricity demand to power air conditioning are also a key reason why fossil fuel emissions have continued to rise despite the massive boost in renewables in 2024, says Neil Grant at Climate Analytics, a think tank in Germany. Whether due to electric vehicles, manufacturing or data centres, most people have been surprised by the level of electricity demand this year, he says.

If emissions continue at this level, the report finds that within six years the world will exceed its remaining carbon budget to limit warming to 1.5°C above pre-industrial levels, and will exceed the budget to stay within 2°C warming within 27 years.

"Climate change is like a slippery slope that we can just keep falling down. We need to slam on the brakes as hard as we can so we can stop falling," says Canadell.

We have warmed the planet by 1.5°C since 1700

Bubbles of air trapped in ice reveal that humans have already caused about 1.5°C of warming since the start of the industrial revolution.

Measurements of human-caused global warming generally use the period from 1850 to 1900 as the pre-industrial baseline, because this is when temperature records began. 2024 is almost certain to be the first year where average temperatures rose more than 1.5°C above this baseline.

However, once natural factors that affect global temperatures are removed, scientists think humanity has caused 1.31°C of warming since the industrial revolution. But by 1850, the industrial revolution was already well under way.

Andrew Jarvis at Lancaster University and Piers Forster at the University of Leeds, both in the UK, have analysed air bubbles in ice cores to establish the atmospheric carbon dioxide concentration from AD 13 to 1700, before humans had a big impact on atmospheric temperatures. They used the CO_2 data to establish global mean temperatures for the period (*Nature Geoscience*, doi.org/nr7g).

Using this pre-1700 baseline, humanity had caused 1.49°C of warming by 2023, meaning the 1.5°C level "has now in effect been reached", the pair write.

Madeleine Cuff

Health

Oral microbiome linked to cancer

Microbes are increasingly being implicated in the onset of head and neck cancer, but there is still a lot that we need to learn, reports **Linda Geddes**

MOUNTING evidence suggests that the microbes in our mouths could be putting us at risk of certain cancers – and affecting our prognosis if we do develop them.

The mouth is home to a diverse microbial community, with more than 700 species of bacteria alone. Over the past decade, research has increasingly linked gum disease and the microbes that arise through poor oral hygiene to various conditions, including Alzheimer's disease and arthritis. Evidence is also implicating the oral microbiome in head and neck cancers, which can start in more than 30 places, including the mouth and throat.

Until recently, most of these studies were small and they only flagged certain groups of bacteria in people who already had cancer, making it unclear whether they were drivers of the condition or merely correlative passengers.

But in September, researchers led by Soyoung Kwak at the New York University Grossman School of Medicine edged closer to clearing up that uncertainty. The team analysed data from three investigations that are tracking the health of 159,840 people in the US. Saliva samples were taken at the start of the studies.

Around 10 to 15 years later, the development of head and neck squamous cell carcinoma – which affects the mucous membranes lining the mouth, nose and throat – was correlated with the presence of up to 13 bacterial species in the saliva samples.

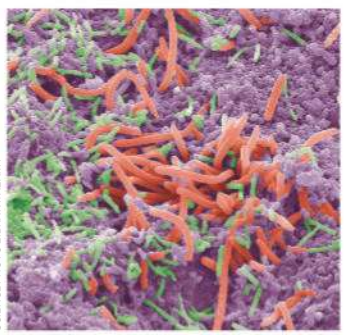
The researchers also detected a moderate association with orange and red complex bacteria, which have a strong link to gum disease.

The study wasn't designed to establish cause and effect, but it still provides some of the strongest evidence yet that certain bacteria may be associated with the development of cancer.

"I think this is another reason to keep up good oral hygiene," says team member Richard Hayes, also at NYU Grossman School of Medicine.

Other research groups have been unpicking the mechanisms through which certain oral bacteria might influence our cancer susceptibility. Earlier this year, Jason Chan at the Chinese University of Hong Kong and his colleagues identified seven species that were particularly enriched in oral cavity tumours, but not healthy tissue. Further experiments suggested that they correlate with the upregulation of genes involved in cell proliferation, migration and adhesion – pathways that are often dysregulated in cancer.

"Head and neck cancer is an underserved disease, so there is a lot of room for improvement"



SCIENCE PHOTO LIBRARY/ALAMY

***Fusobacterium nucleatum* bacteria seem to play a role**

"Our study suggests that bacteria do play a role in these cancers and seem to drive their development – particularly, we think, at an early stage," says Chan.

One species identified in both studies is *Fusobacterium nucleatum*, a key member of the red complex bacteria. Earlier lab-based research by Ofer Mandelboim at the Hadassah-Hebrew University in Jerusalem and his colleagues found that this species helped to protect cancer cells from immune attack.

This could provide tumours almost free rein to grow, says Miguel Reis Ferreira at King's College London.

But recent research by Reis Ferreira's own group suggests that the relationship isn't clear-cut. His team found that people with head and neck cancer who have higher levels of *F. nucleatum* actually have a better prognosis than those with lower levels. Lab experiments also identified a large reduction in viable cancer cells upon infection with *F. nucleatum* bacteria. "They essentially melt head and neck cancer cells," he says.

Referring to the research by Hayes and Kwak's team, Reis Ferreira says that while this was a very large study, it doesn't prove that red or orange complex bacteria cause cancer. "It could just be an association, because these bacteria thrive in environments where there's a lot of inflammation, and inflammation is a known risk factor for cancer."

But understanding these relationships is clearly important. "Head and neck cancer is an underserved disease, and the treatment hasn't really evolved very much, so there is a lot of room for improvement," he says.

One hope is that some of these bacterial profiles could be used in combination with lifestyle information to classify people into high or low-risk groups for developing head and neck cancer.

Altering the oral microbiome might also affect people's outcomes, says Chan. "We know from melanoma studies that manipulating the gut microbiome can improve their response to immunotherapy. So, through the microbiome, could we influence treatment outcomes for patients with head and neck cancer?" ▮

THOMAS BARWICK/GETTY IMAGES

Warding off cancer may be yet another reason to prioritise dental hygiene

Neuroscience

New twist on famous invisible gorilla psychology study

Michael Le Page

ALLISON MICHAEL ORENSTEIN/GETTY IMAGES

You might see a person in a gorilla suit without realising it

WHEN we focus on one task, we often fail to notice something obvious in our field of view. This phenomenon, known as inattentional blindness, was famously demonstrated in a study involving a person in a gorilla suit, which people failed to spot. Now it seems the gorilla isn't so invisible, and we do actually take in information even when we might miss the wider picture.

In a classic experiment from 1999, Daniel Simons and Christopher Chabris, then at Harvard University, made a short video featuring people passing basketballs. Halfway through the video, someone in a gorilla suit walks through the shot. When volunteers were asked to count the number of passes made by people in white t-shirts, only half reported seeing the gorilla.

"I showed my daughters the famous gorilla demonstration, and one of them couldn't believe that there had been a gorilla there, and I remember that experience myself," says Ian Phillips at Johns Hopkins University in Baltimore, Maryland.

The results of some other studies made him think that simply asking people if they saw something unexpected might not reveal the full picture. To test this, Phillips and his colleagues got 25,000 people to do one of five experiments online for a small fee.

In the first experiment, people were asked to look out for crosses appearing on a screen for 0.2 seconds and say whether the horizontal or vertical arms of the cross were longer. On the fourth occasion, a red line appeared on one side of the screen as well as the cross.

"One of my daughters couldn't believe that there had been a gorilla there"

When volunteers were asked, "Did you notice anything unusual on the last trial that wasn't there on previous trials?", 71 per cent said yes.

But when they were told that a red line appeared on one side of the screen and were asked which side it was on, 87 per cent chose the correct side. Of those who replied no to the first question, 64 per cent chose the correct side, far more than the 50 per cent that would be expected by chance. The results of the other four experiments were similar (bioRxiv, doi.org/nr65).

"I think it shows clearly that people might well have processed some information about the critical unexpected object even when they reported not having seen it," says Simons, who is now at the University of Illinois Urbana-Champaign and wasn't involved in the new study. "We should be wary of attributing that to anything subliminal or subconscious, though."

Phillips thinks the simplest explanation for his findings is that some people were partly aware of the unexpected object, but were reluctant to say they saw it when they weren't sure.

"So, that's a bias in relation to saying whether they saw something or not," he says. "And the point about it being a bias is that it's something you can work with. You could potentially try to train people in fields where it is really important they don't miss things."

Phillips says the study is in no way debunking the notion of inattentional blindness. "It shows that there really is something very striking going on when attention is consumed by another task," he says. It is just that people may not be as unaware as previously assumed. ▮

Genetics

Sweeter tomatoes are coming thanks to gene editing

IF YOU like your tomatoes sweet, the smaller cherry tomato varieties are currently the ones to go for. But bigger tomatoes could soon get a genetic sweetness boost.

The bigger a tomato, the lower its sugar content usually is, says Jinzhe Zhang at the Chinese Academy of Agricultural Sciences in Beijing. Efforts to boost the sweetness of larger varieties have had downsides, such as lowering yields.

CLARE HARGREAVES/ALAMY

Gene editing can make larger tomato varieties, like Moneymaker, sweeter

So Zhang and colleagues compared varieties to identify genetic variants that affect sweetness. They found that two related genes called *SlCDPK27* and *SlCDPK26* are more active in large varieties. These genes code for proteins that lower the levels of an enzyme that produces sugars.

When the team used CRISPR gene editing to disable these genes in a variety called Moneymaker, the levels of glucose and fructose in the fruits increased by up to 30 per cent with no decrease in yield. The fruits were also rated as sweeter in a taste test. The only other effect was fewer and smaller seeds, which consumers may prefer (*Nature*, doi.org/nr68).

"We are working with some companies to develop some commercial varieties by knocking out these genes," says Zhang.

The gene-edited Moneymaker tomatoes aren't as sweet as cherry varieties such as Sungold, but it should be possible to boost sweetness further, says Zhang. "There are still many important genes that regulate sugar waiting to be discovered." ▮ MLP

Health

Weight-loss drugs may treat pain

In mice, the medications effectively treated many types of pain, both chronic and acute

Grace Wade

MEDICATIONS like Ozempic and Wegovy may be able to reduce both chronic and acute pain. This makes these types of drugs promising safer alternatives to pain treatments such as opioids, though the effect has yet to be demonstrated in humans.

Ozempic and Wegovy work by mimicking a hormone released after eating known as GLP-1, which reduces appetite and regulates blood sugar levels. While these medications are only approved for treating obesity and type 2 diabetes, studies have shown that they have a surprisingly wide range of effects: they have shown promise for helping to treat other conditions from Alzheimer's disease to mental health conditions to addiction.

Previous research has shown that animals experience less pain after eating. This prompted Yong Ho Kim at Gachon University in South Korea and his colleagues to investigate whether GLP-1 could be mediating this effect.

The researchers treated five mice with GLP-1 and then measured how quickly the animals retracted their paw from a heated surface. They found that, on average, mice kept their paw on the heated surface for roughly 1.25 times as long as they did when they weren't treated with GLP-1. This wasn't the case for a separate group of animals treated with salt water, suggesting the hormone reduces sensitivity to pain.

They did further measurements of neural activity and found that GLP-1 blocks a receptor in nerves called TRPV1, which is crucial for eliciting pain. Kim and his team identified the molecule on GLP-1 that binds to this receptor and then treated six mice with a synthetic version of this molecule called exendin 9-39.

On average, the animals took about 1.25 times as long to remove their paw from a hot beam of light when treated with the molecule than when they weren't. This effect persisted for up to 2 hours after the mice received treatment (*Experimental & Molecular Medicine*, doi.org/nr9n).

"GLP-1 is so effective at targeting the entire brain, so there are other things it could potentially be doing"

Exendin 9-39 was also effective at treating other types of pain in mice, including nerve pain, inflammatory pain and chronic pain. The molecule also didn't produce any metabolic effects in the rodents, such as reducing blood sugar levels or dampening appetite. That is because it specifically targets TRPV1, says Kim, who presented these findings at an October meeting of the Society for Neuroscience in Chicago.

Past experimental drugs designed to act on TRPV1 have been shown to raise body temperature to dangerously high levels. Yet Kim and his team didn't find this to be true in mice treated with exendin 9-39.

Together, these results suggest that exendin 9-39 could be a safe and effective treatment for multiple types of pain, says Kim. Current pain medications, such as opioids, aren't effective at treating chronic pain and come with serious side effects, such as a high risk of addiction.

This research also underscores just how much more we have to learn about the sweeping effects of drugs that mimic GLP-1, says Karolina Skibicka at Pennsylvania State University, who wasn't involved in the study. "Because GLP-1 is so effective at targeting the entire brain, there are also other things it could potentially be doing," she says. ▮

Technology

Autonomous cars do doughnuts and slide round corners

TOYOTA is teaching driverless cars to deliberately skid sideways at high speed while safely navigating a course. The firm says the technique wouldn't be used on roads as part of the normal driving experience, but could help an autonomous car recover from skids in an emergency.

Drifting is a driving technique in which drivers intentionally lose traction but maintain control to slide the car sideways around corners. Drifting cars around tracks has become a sport in its own right.

Now, a team of researchers at the Toyota Research Institute (TRI) in California has shown that a driving artificial intelligence model can make a Toyota GR Supra or Lexus LC 500 drift smoothly around a course with multiple turns, sliding within 10 centimetres of targets. The cars, which have a driver inside in case things go wrong, enter a skid and screech sideways at angles as large as 63 degrees off their direction of travel (arXiv, doi.org/nr7c).

The researchers say an AI that can do this could be useful in extreme circumstances. "When a vehicle is driving and unexpectedly hits a patch of ice on the road, we need our AI to control the vehicle at its limits to ensure safety," says Avinash Balachandran, who researches autonomous driving at the TRI, but wasn't involved in this work.

Colin Hoad, who drives drift cars and teaches test drivers at CAT Driver Training, says the research goes beyond situations that will generally arise in the real world. "But you could imagine that if the vehicle had that skill, it might save you from a 1-in-a-million incident," he says. ▮

Matthew Sparkes

TOYOTA RESEARCH INSTITUTE

A time lapse of a Toyota GR Supra drifting around a corner under the control of artificial intelligence

Astronomy

Galaxies make a zigzag lens

Light from a distant quasar is being deflected by not one but two massive galaxies, giving us a unique opportunity to probe the expansion of the universe, reports **Alex Wilkins**

A CHANCE alignment between two massive galaxies could help astronomers better measure the expansion of the universe and shed light on the mysterious nature of dark energy.

While working on his general theory of relativity, Albert Einstein predicted that light from distant galaxies and stars should be bent by the gravity of very massive objects, similar to how a glass lens bends and magnifies light. Astronomers have since observed hundreds of galaxies, or clusters of galaxies, acting as gravitational lenses, warping and sometimes duplicating the images of galaxies that are sitting behind them.

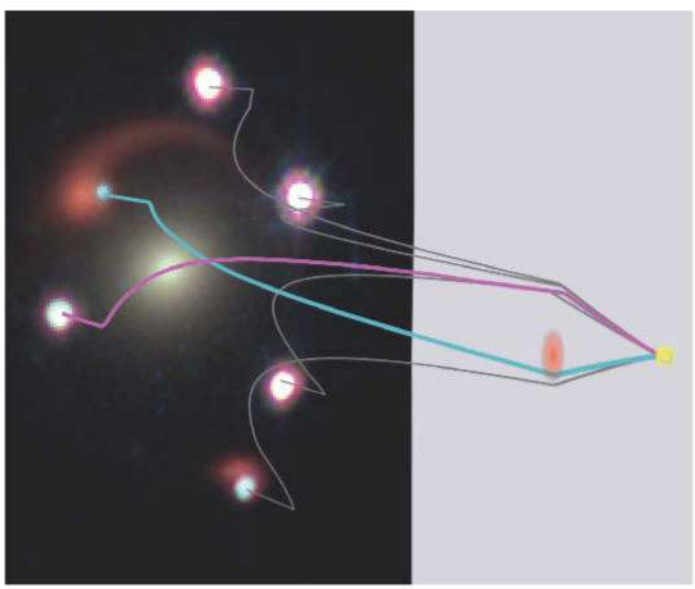
Now, Martin Millon at Stanford University in California and his colleagues have found an incredibly rare case of two galaxies, 13.4 billion light years apart, both bending the light of a quasar, an incredibly bright supermassive black hole at the centre of a third galaxy.

"This is the only [double gravitational lens] that has been found so far," says Millon. "It's probably a 1-in-50,000 gravitational lens, but we haven't found 50,000 lensed quasars. There's only 300, so it's super strange that we found one."

Astronomers have described this configuration as an "Einstein zigzag lens". The resulting image contains six copies of the original, some of them flipped due to the complicated path that the quasar's light took between the two gravitational lenses.

"We've never seen anything like this before," says Thomas Collett at the University of Portsmouth, UK. While there have been alignments of more than two galaxies, the lensing from the second galaxy has normally been so small as to be irrelevant, he says.

The lens was first spotted in 2021, but astronomers concluded that it was a single lens distorting two quasars behind it. "You can see there is this big, bright yellow galaxy in the centre – that's the main lensing galaxy – and then there is this red arc that was interpreted as another galaxy at the same distance as the source," says team member Frédéric Dux at the Swiss Federal Institute of Technology in Lausanne.



F. DUX ET AL. (2024)

This black square shows six points of light as they appear when viewed in 2D through a telescope, but these are actually all the same quasar. The 3D view shows how light from the quasar (yellow spot) is deflected by two galaxies: one of which is represented by the red spot, the other by the central glow in the black image

15.8 billion
Distance to the furthest lensing galaxy from Earth in light years

13.4 billion
Distance between the two lensing galaxies in light years

1 in 50,000
Proportion of lensed quasars expected to have a zigzag lens

However, new observations with the Nordic Optical Telescope in the Canary Islands and the James Webb Space Telescope revealed that this red arc was in fact a closer galaxy acting as a second lens (arXiv, doi.org/nsc6).

One advantage of seeing a lensed object duplicated six times, rather than four times, which is the standard for a single-source lens, is that it can be used to calculate a more accurate value of the Hubble constant, which measures the rate of expansion of the universe. This could help settle a long-standing cosmological debate over two very different values for the Hubble constant given by two different measurement techniques.

The same pattern of four images can be produced under different values for the Hubble constant depending on how spread out the mass in the lensing galaxy is, but astronomers can't separate out these scenarios. With two lenses, however, you can differentiate between them and measure the Hubble constant more precisely, says Millon.

One of the lensing galaxies is also the most distant lens we know of, at 15.8 billion light years. This presents a unique opportunity to accurately measure the mass of very early galaxies, says Collett. "The really exciting thing here is learning about [this] lens, this galaxy that's halfway to the edge of the universe."

Dark energy clues

Gravitationally lensed systems are one of the most accurate methods we have of measuring the mass of galaxies, but because galaxies in the early universe often haven't had time to grow to a size where they can act as gravitational lenses, there is a gap in our knowledge. "This is the first real opportunity to understand the make-up and contents of galaxies at such a high [distance from Earth], and that's very exciting," says Collett.

The lens system could also tell us about the expansion rate of the universe in the past, at the age of the more distant galaxy. This is tied to the nature of dark energy, the mysterious force that appears to be accelerating the expansion of the universe, says Millon. Measuring the Hubble constant using the double lens system could therefore provide clues to how dark energy accelerated the expansion of the universe in the past billion years, he says. ▮

Space

Twin spacecraft will launch to create an artificial solar eclipse

Jonathan O'Callaghan

THE European Space Agency (ESA) is aiming to create an artificial eclipse in space with its upcoming Proba-3 mission, which will help study the sun and demonstrate extremely precise formation flying.

Scheduled to launch on an Indian PSLV-XL rocket on 4 December, the mission comprises two spacecraft. After launch, they will be placed into a highly elliptical orbit around Earth that comes as close as 600 kilometres to the planet, but as far as 60,000 kilometres from it.

150
Distance in metres between the two spacecraft flying in close formation

One spacecraft, called the Occulter, is equipped with a 1.4-metre-wide disc made of carbon fibre and plastic. The other spacecraft will fly about 150 metres behind the first, pointing a camera towards it. From this vantage point, the Occulter's disc will block out the surface of the sun, just as the moon appears to cover the sun during a total solar eclipse. This will allow the imaging craft to view the solar corona, the sun's atmosphere, in unprecedented detail.

"It will be the closest to the sun we have observed the corona in visible light," says Damien Galano, the mission manager for Proba-3 at ESA. "This can give us some specific information about the temperature of the corona, the creation of solar wind and how the corona expands into space."

Proba-3 will achieve this feat by flying with incredible precision. Both spacecraft are laden with sensors to track their position and the Occulter will use 12 nitrogen thrusters to autonomously maintain position with its partner to a single millimetre in accuracy. The thrusters can eject just 10 millinewtons of thrust, 50 times less force than a human breath. ▮

Analysis Social media

Can Australia's planned social-media ban for under-16s work?

Attempts to prevent children from accessing online platforms could do more harm than good, finds **James Woodford**

A PLAN to ban all Australian children under 16 from social media is unworkable, unenforceable and won't help the people it aims to protect, experts have told *New Scientist*.

While social media platforms are banned outright in some authoritarian regimes, no democratic country has gone as far as the proposal from Australian Prime Minister Anthony Albanese in completely restricting them for under-16s.

"Social media is doing social harm to our kids. I'm calling time on it," said Albanese on 8 November. Legislation due to be introduced before the end of the year will have no exemption for parental consent or for pre-existing accounts, which will simply be deleted. Which platforms will be included in the ban is unclear, but it is expected to include Instagram, Snapchat, TikTok, Facebook and YouTube.

Concerns are already being raised. "It's ill-thought through hot air that will not be enforceable," says Susan McLean, one of Australia's leading cyber safety experts.

A key problem with enforcement is age verification. The government is planning a trial of technology meant to determine whether a user is 18 or older, or between 13 and 16, which is expected to examine various biometric and ID criteria. Similar efforts to limit access to adult content in the UK with age verification systems were delayed and eventually abandoned as unworkable.

Even if Australia does develop solutions, teenagers are likely to find technical workarounds to the ban, such as using virtual private network (VPN) services, which allow users to pretend to be visiting a social platform from another country. "This ban is virtually impossible," says Lisa Given at the Royal Melbourne Institute of Technology.

It is also unclear why the government has chosen 16 as the cut-off point. "No magic happens at the age of 16 to make you ready for the challenges of trolls, bullying and pornography and all the other problems online," says Given.

Catherine Page Jeffery at the University of Sydney says studies have found links between social media use and psychological harm in under 16s, but evidence of causation is "not clear at all".

This sentiment is echoed by McLean. "Sixteen is a nothing number, not linked to any level of cognitive development and plucked out of thin air," she says. She supports 13 as a more realistic age to set the entry point to access social media, but says this is linked to a precedent set by US legislation in the 1990s rather than scientific evidence.

For her part, Jeffery is sceptical of 13 as a cut-off point, saying it is also "not related to any physical or developmental milestones".

Instead of banning children from social media platforms, Given says the government should force the firms behind the platforms to clean up their content by using more moderators and better algorithms to promptly remove inappropriate content.

"An outright ban will mean some kids will start to access social media in secret, and that raises the risk of it being more harmful for them," she says.

While many parents are supportive of a ban, others see it as an overreach and fear the damage that will be done to teenagers engaged in positive activities online, says Given. She highlights the case of 6 News Australia, a channel that primarily publishes the journalism of teenagers and relies on access to social media to research stories. Leo Puglisi, who founded 6 News when he was 11, recently told a parliamentary committee that without social media his outlet "simply wouldn't exist".

McLean also fears for children who are neurodivergent or are members of the LGBTQ+ community. "Many of them have found their support community online," she says. "What a cruel thing it would be to take that away." ▮

Australian Prime Minister Anthony Albanese wants to restrict access to social media

LUKAS COCH/AAP/IMAGO

Technology

AIs converse better in own language

Using a mathematicial dialect called Droidspeak helps speed up AI communication

Matthew Sparkes

MICROSOFT has created an artificial language that allows AI models to talk to each other faster and more efficiently than in English, with the hope that groups of models will be able to team up without having to resort to clumsy and sprawling human words.

Many researchers believe that using several artificial intelligence models, each with different specialisms and abilities, to solve problems collectively holds promise for tackling thorny problems that individual ones can't solve. Although large language models like ChatGPT have been shown to be capable of communicating at high speed, even reaching consensus in groups of up to 1000, designing these models to talk to each other in a language like English – as humans would talk to them or each other – creates a significant bottleneck.

Now, Madan Musuvathi at Microsoft and his colleagues have created a language called

JIM STOCK PHOTOGRAPHY/ALAMY

Droidspeak is named for the beeping dialect "spoken" by R2-D2 in the *Star Wars* films

Droidspeak to streamline that communication. Named after the beeping dialect "spoken" by R2-D2 in the *Star Wars* films, the language is essentially a mathematical shorthand for evoking certain words, concepts or instructions.

Most current AI models take English prompts and split them into a series of tokens, which can be anything from individual characters to words or even whole phrases. This string of tokens is then turned into a mathematical description of the complex path taken by each token as it is processed by the AI's neural network. These paths embed conceptual and factual information about language.

For instance, the individual paths for the words "king" and "queen" will be more similar to each other than "king" and "ball" are. The paths can also be manipulated mathematically, such as by taking "king", subtracting "man", adding "woman" and coming up with a path for "queen".

"It's not working in words, it's not working in tokens, it's working in high-dimensional space," says Philip Feldman at the University of Maryland, Baltimore County, who wasn't involved in the work. "These are very complicated [paths]."

Droidspeak uses the mathematics of the paths to remain working in this high-dimensional space, rather than converting into text and back, which the researchers say is 2.78 times faster and has negligible accuracy loss. But there is a catch: currently, it only works with multiple copies of the same AI model. The researchers hope to investigate how to apply the concept to models that differ from each other (arXiv, doi.org/nsb9).

Feldman says the approach will speed up communication between AI models and could also make collections of models more powerful and able to tackle larger and more complex problems.

2.78

AIs could collaborate this many times faster using Droidspeak

He points out that similar ideas have been used in the past to attack AI and get it to do things that the makers want to prevent. For instance, if a model checks inputs for dangerous keywords like "bomb recipe", you can't get it to tell you how to make a bomb. But by working out the path for a sequence of words that conveys the same meaning, you may be able to input that to a model and sidestep the safety mechanisms. ▮

Ecology

Gophers restored ruined landscape after eruption

TWO years after Mount St Helens in Washington state erupted in 1980, researchers helicoptered in gophers. Decades later, it seems the gophers' activity for a single day in the ash-covered landscape may have helped the ecosystem regrow.

The northern pocket gophers (*Thomomys talpoides*), native to the area, were placed individually in enclosures in a formerly forested area deeply buried by the eruption's pyroclastic flows – now known as the Pumice plain – and given 24 hours to dig around and defecate. "Bringing them there was like bringing a mini-ecosystem just for a short time," says Mia Maltz at the University of Connecticut.

More than four decades later, Maltz and her colleagues surveyed the fungi and other microbes in the soil in the gopher enclosures, and in nearby areas that weren't exposed to the animals. They also surveyed soil in areas that weren't as deeply buried as the Pumice plain, in what had been old-growth forest and an area cleared by loggers before the eruption.

They found that gopher-exposed soil contained a greater diversity of fungi than even the former old-growth forest areas, especially the mycorrhizal fungi that colonise plant roots and help plants access nutrients. The old-growth areas, meanwhile, contained more of this fungal diversity than the logged areas (*Frontiers in Microbiomes*, doi.org/nr6t). "It was remarkable how different these communities were," says Maltz.

RICK & NORA BOWERS/ALAMY

The activities of northern pocket gophers can boost an area's fungal diversity

This microbial diversity in turn seems to have supported more vegetation in gopher-exposed areas, preventing soil erosion there in ways still visible four decades after the gophers were helicoptered away. By digging up fungal spores buried by the ash flow and introducing microbes living under their claws and in their droppings, the gophers "were bringing little pockets of productivity to the surface", says Maltz. ▮

James Dinneen

Physics

Jets of fluid can levitate above a scorching hot pan

Karmela Padavic-Callaghan

A JET of liquid can bounce off a hot plate without ever touching it. This extension of the Leidenfrost effect – the phenomenon that allows beads of water to skitter across a sizzling pan – could help improve cooling processes, like those used in nuclear reactors.

Although first described nearly 300 years ago, the Leidenfrost effect had only been tested with fluid droplets, not squirts of liquid.

Franck Celestini at Côte d'Azur University in France and his colleagues experimented with ethanol instead of water because it is more volatile – it vaporises more quickly. They shot a jet of the liquid, about the size of a stream of water from the tap, onto a plate heated to between 200°C (400°F) and 300°C (570°F). The researchers varied the speed of the jet and the angle at which it hit the plate, recording the process with a high-speed camera.

They found that jets could ricochet from the plate without touching it. This strange effect is possible because of a layer of steam that forms above the plate, cushioning the jet. But this "Leidenfrost jet" didn't happen in all instances. Depending on the temperature of the plate, the amount of ethanol being jetted onto it and the jet's speed, the fluid only levitated if shot from an angle steeper than 50 degrees (*Physical Review Fluids*, doi.org/nr4q).

Although this was tested with ethanol, Celestini says he expects that water jets would behave similarly.

The work could have implications for industrial cooling processes such as cooling nuclear reactors, says Justin Burton at Emory University in Atlanta, Georgia. That is because cooling hot reactors by spraying them with water becomes ineffective if some of the spray never touches the reactor surface. ▮

Archaeology

12,000-year-old stones may be oldest example of wheel-like tools

Christa Lesté-Lasserre

NAFTALI HILGER

LAURENT DAVIN

A perforated pebble (above) from the Nahal Ein Gev II archaeological site (left) near Lake Kinneret in Israel

A SET of 12,000-year-old pierced pebbles excavated in Israel may be the oldest known hand-spinning whorls – a technology that could have inspired the invention of the wheel.

Serving as a flywheel at the bottom of a spindle, whorls allowed people to efficiently spin natural fibres into yarns and thread to create clothing and other textiles. The stone tools represent axle-based rotation technology thousands of years before the first carts, says Talia Yashuv at the Hebrew University of Jerusalem.

"When you look back to find the first vehicle wheels 6000 years ago, it's not like it just came out of nowhere," she says. We need to look at the functional evolution of wheels, she adds.

Yashuv and her colleague Leore Grosman, also at the Hebrew University of Jerusalem, studied 113 perforated stones at the Nahal Ein Gev II site, an ancient village just east of Lake Kinneret, also known as the Sea of Galilee. Archaeologists have been uncovering these chalky, predominantly limestone artefacts – probably made from pebbles from the nearby seashore – since 1972.

3D scanning revealed that the holes had been drilled halfway through from each side using a flint hand drill, which – unlike modern drills – leaves a narrow and twisting cone-like shape. Measuring 3 to 4 centimetres in diameter, the holes generally ran through the pebble's centre of gravity.

Drilling from both sides would have helped balance the stone for stable spinning, says Yashuv.

6000

years ago is roughly when the first vehicle wheels appeared

The team suspected that the stones, weighing 9 grams on average, were too heavy and "ugly" to have been beads and too light and fragile to be used as fishing weights, says Yashuv. Their size, shape and balance around the holes convinced the researchers that the artefacts were spindle whorls (*PLoS One*, doi.org/g8qw8p).

To test their hypothesis, the researchers created replica whorls using pebbles and a flint drill. They then asked traditional craftsperson Yonit Kristal to spin flax with them.

"She was really surprised that they worked, because they weren't perfectly round," says Yashuv. "But really you just need the perforation to be located at the centre of mass, and then it's balanced and it works."

If the stones are whorls, that could make them the oldest known spinning whorls, she says. A 1991 study on bone and antler artefacts uncovered what may be 20,000-year-old whorls, but the researchers who examined them suggested the pieces were probably decorative clothing accents. Even so, it is possible that people were using whorls even earlier, made from wood or other biological materials that would have since deteriorated.

The finding suggests that people were experimenting with rotation technology thousands of years before inventing the pottery wheel and the cart wheel, says Yashuv.

Carole Cheval at Côte d'Azur University in Nice, France, isn't convinced the artefacts were precusors to wheels. Whorls work more like a spinning top than a wheel, she says. And while they may be whorls, the study lacks microscopic data that would reveal traces of use – as yarns would have marked the stones over time, says Cheval. ▮

Marine biology

World's largest coral found

This 300-year-old colonial organism is larger than a blue whale

Madeleine Cuff

IN THE south-west Pacific, off the coast of one of the tropical Solomon Islands, this giant structure beneath the water's surface has just been identified as the world's largest known coral.

"It is enormous," underwater cinematographer Manu San Félix told reporters during a briefing. "The size is close to the size of a cathedral."

The coral lies a few hundred metres off the coast of Malaulalo Island and has been identified as the species *Pavona clavus*. It is 34 metres by 32 metres across and about 5.5 metres tall, making it larger than a blue whale, and is thought to be 300 years old.

It is the largest single coral colony ever discovered, easily beating the previous record holder – a giant *Porites* colony found in American Samoa in 2019, which was 22.4 metres in diameter and 8 metres in height.

MANU SAN FÉLIX/NATIONAL GEOGRAPHIC SOCIETY

Space

Our only visit to Uranus was at a weird time

URANUS'S strange magnetic field may be much less odd than astronomers first thought, which means its largest moons could be far more active, and even perhaps have global oceans.

The only direct measurements we have of Uranus's magnetic field come from NASA's Voyager 2 spacecraft, which flew past the planet in 1986.

The spacecraft's readings suggested that the magnetic field was lopsided – meaning it wasn't aligned with the planet's rotation – as well as being unusually rich in extremely energetic electrons and devoid of the plasma that is common in the magnetic fields of other gas giants like Jupiter.

Astronomers at the time thought the results so bizarre that they invoked complex physics to try to explain the readings – or simply dismissed them as evidence that Voyager 2's instruments had gone haywire.

"Everything we thought we knew about Uranus's magnetic field might be wrong"

Now, Jamie Jasinski at NASA's Jet Propulsion Laboratory in California and his colleagues have reanalysed the Voyager 2 data and found that it was skewed by a rare burst of solar wind that squashed Uranus's magnetic field just before the spacecraft arrived, disturbing the readings. This means everything we thought we knew about Uranus's magnetic field might be wrong, says Jasinski. "This kind of almost resets everything."

He and his team found that the solar wind compressed Uranus's magnetic field to a size that it would typically only adopt 4 per cent of the time – but that scientists have, for the past 40 years, assumed was its normal state (*Nature Astronomy*, doi.org/nr7m). The squashed magnetic field explains the previous strange results, such as its lack of plasma and highly energetic electrons, says Jasinski.

If there is, in fact, plasma in Uranus's magnetic field – and Voyager 2 just happened to miss it – then it might not all come from the planet itself. Some might come from Uranus's moons, the largest of which are called Titania and Oberon. Until now, we have assumed that these moons were inert, but the new study leaves open the possibility that they are geologically active after all.

This would fit with recent calculations indicating the moons might have hidden oceans. "The solar wind could have essentially eradicated all the evidence of active moons just before the flyby happened," says Jasinski.

Alex Wilkins

Health

Evidence mounts that air pollution can cause eczema

Carissa Wong

AIR pollution is increasingly being linked to a raised risk of eczema, with a new study showing a clear relationship between exposure and the skin condition.

Vehicles and power plants release pollutant particles with a diameter of 2.5 micrometres or less, called PM2.5. These have previously been linked to a higher risk of eczema, which is thought to be the result of an overactive immune system causing inflammation that makes skin dry and itchy.

To gather more evidence, Jeffrey Cohen at the Yale School of Medicine and his colleagues analysed the medical records of more than 280,000 people who took part in the All of Us Research Program and were mostly in their 50s. This project collects health data from a diverse group of people in the US.

The researchers also looked at average PM2.5 levels where these people lived, using data collected in 2015 by the Centre for Air, Climate, and Energy Solutions in Virginia.

Then, they compared PM2.5 levels in 788 locations across the US against eczema cases, which were diagnosed up until mid-2022. They found that for every 10 microgram per cubic metre increase in PM2.5, eczema rates more than doubled (*PLoS One*, doi.org/nr44). "In more polluted areas of the country, there was more eczema," says Cohen.

"The study brings forward the science by nicely showing a clear correlation in a large population," says Giuseppe Valacchi at North Carolina State University.

PM2.5 may trigger the immune system to cause inflammation when it comes into contact with skin, like pollen or dust mites can, or when inhaled, says Valacchi.

This research should give governments another reason to enforce policies that reduce air pollution, says Cohen.

Zoology

Migratory birds use Earth's magnetic field like GPS

Christa Lesté-Lasserre

MANY migratory birds use Earth's magnetic field as a compass, but some can also use information from that field like a sort of GPS that tells them not only which direction to go, but also where they are initially.

"When we travel, we have a map – which tells us where we are – and we have a compass, which tells us which way to go to reach our destination," says Richard Holland at Bangor University in the UK. "We don't think birds have quite this level of accuracy or degree of knowledge of the whole Earth. Even so, they see how magnetic cues change as they move."

Scientists have known for decades that migratory birds rely on cues from the sun, the stars and Earth's magnetic field to determine which direction to head towards.

But figuring out direction using a compass is very different from birds knowing where they are, and scientists still debate about whether – and how – birds figure out their current map position.

Holland, Florian Packmor at Lower Saxon Wadden Sea National Park Authority in Germany and their colleagues turned to Eurasian reed warblers (*Acrocephalus scirpaceus*) to see if the birds could use two metrics to detect where they are: magnetic inclination, the changing angle of Earth's surface relative to its magnetic lines, and magnetic declination, the difference in direction between the magnetic and geographic poles.

"Figuring out direction using a compass is very different from birds knowing where they are"

They captured 21 adult reed warblers on their migration route from Europe to Africa in Illmitz, Austria. The researchers temporarily placed the birds in outdoor aviaries, where they used a Helmholtz coil to interfere with magnetic fields. They artificially altered the inclination and declination in a way that corresponded to a position in Neftekamsk, Russia, about 2700 kilometres away. "That's way out of their direction," says Packmor.

The team then put the birds in a special cage for studying migratory instincts and recorded which way the birds headed. In the modified magnetic field situations, most of the birds showed a clear penchant for flying west-south-west, as though they were trying to return to their migration route from Russia.

By contrast, the same birds wanted to fly south-south-east out of Austria when the magnetic field was unmodified (*Proceedings of the Royal Society B*, doi.org/nr4g).

This suggests that the birds believed that they were no longer in Austria, but in Russia – based on their magnetic inclination and declination alone, says Packmor.

"Of course, they don't know it's Russia, but it's too far north and east of where they should be," says Holland. "And then at that point, they look at their compass system to work out how to fly south and west."

However, we still don't fully understand the neurological mechanisms that enable birds to sense these aspects of Earth's magnetic field.

"This is an important step in understanding how magnetic maps of songbirds – and in particular, reed warblers – work," says Nikita Chernetsov at the Zoological Institute of the Russian Academy of Sciences in Saint Petersburg.

While the research confirms that reed warblers rely on these magnetic fields for positioning, it doesn't mean that all birds do so, he adds. "Not all birds work the same way."

AGAMI PHOTO AGENCY/ALAMY

Eurasian reed warblers migrate between Europe and Africa

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An MSF surgical team at Al-Shifa's burn unit in Gaza city cleans the wound of a child after a burn injury.
Photograph © Tetiana Gaviuk/MSF

DR JAVID ABDELMONEIM IS AN MSF DOCTOR RECENTLY RETURNED FROM WORKING IN GAZA.

"At Nasser hospital, we provide trauma surgery and burns care to patients. One Saturday early in my time there, we received hundreds of injured, as well as people who had been killed, following a missile strike.

It was chaos. Our team went to the emergency room. One of the injured was a three-year-old girl. She was breathing and looking at me – so she must be okay, I thought. But as I rolled down her dressing, I found that her entire left thigh was open to the bone.

Seconds later, the doors crashed open. Four to five injured people were brought in, most of them first-aid responders. Among them was a boy who wasn't breathing, so we tried to revive him, but the nurse looked at us and asked: 'Why are we responding to him if he can't breathe? We have to save other lives.' No one had the heart to call it and move on to the next person. He was someone's child. But we had to move on to the next, and then the next, and this continued for another four and a half hours.

In the emergency room, there was blood all over the floor. I had to kneel to see the patients, who were sprawled everywhere because there were no beds left. At the same time, more and more patients were coming in.

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Comment

Erosion of trust

A recent scandal over food hygiene ratings shows how deception destroys trust within society. We need to fight back, says **Jonathan R. Goodman**

UNTIL a few weeks ago, I relied on restaurant hygiene ratings when deciding where to have dinner. The score – given by the UK's Food Standards Agency – ranges from 0 to 5, where 0 indicates urgent improvement is required. It is traditionally a good predictor if you are fastidious – or if you just want to avoid nasty parasites like *Giardia*.

Yet in October, the BBC revealed some businesses misrepresent their hygiene scores, posting a 5 when their ratings are as low as 0. The signal of hygiene I relied on wasn't always reliable.

This was just one incident that had an impact on my trust. Yet it represents something older and more pernicious: deception through misrepresentation undermines trust. As with any social behaviour, when betrayals are successful, they tend to spread, because people copy behaviours associated with success. Over time, this may erode the shared signals on which society depends.

Research in biology and sociology highlights how. Across the natural world, animals signal information to other organisms about themselves: dogs bare their teeth to display a potential for aggression, for example, and male red deer roar to indicate their size.

Some animals, however, cheat. Cuckoo chicks, for instance, mimic the chirps of the young of other birds to deceive adult birds into feeding them. This dishonest behaviour evolved because it works – in an analogous way to how deception spreads, whether biologically or, in the case of humans, culturally.

SIMONE ROTELLA

Among humans, technological improvements allow us to misrepresent our intentions and identities in many ways. This can include masking who we are in digital interactions by "catfishing" and stealing from people online without ever meeting them.

Generative artificial intelligence is only increasing opportunities of this kind. In the book *Fight, Flight, Mimic*, sociologists describe ways AI can be used to deceive people in hostile interactions, even in wars. Early use of voice manipulation, for example, permits people to pose as senior military officials – or even your child in need of money. We share a lot of qualities with cuckoos: anyone can be anyone in the digital age.

Luckily for us, we have found ways to solve problems with trust throughout our history. This is because humans are good at finding out who is trustworthy over time. We learn to recognise patterns of behaviour indicative of deception, and just as the tactics for deception spread, so do the methods for detecting it, whether those involve passwords, face or voice recognition, or any of the new technologies being developed to combat deepfakes.

People are also adept at developing norms that place a cost on deceivers. We have created laws that impose fines or imprison those guilty of impersonation. We are only at the early stages of developing effective rules around AI, but there is a reason we are focusing on the dangers these tools pose to society. That awareness is itself a step in our defence.

What matters for retaining trust is the reliability of the signals we use in communication. It doesn't matter whether we are talking about hygiene scores or phishing emails. What we need is a mechanism for determining reliability: whether people or places can be trusted to do what we expect of them. This is done both through effective policing – sanctioning those who show themselves to be untrustworthy – and through educating ourselves about how to avoid unreliable people, places and things. If I can trust that hygiene ratings are reliable, then I can use the score as a signal to drive my behaviour.

We need to adapt how we learn to place trust and educate people how to spot deception. Even those of us concerned with the accuracy of food hygiene ratings. ▮

Jonathan R. Goodman is the author of *Invisible Rivals: How we evolved to compete in a cooperative world* (2025)

No planet B

A load of rubbish

When I moved back to York, UK, I was shocked by its garbage system, with limited recycling and no composting. But a bit of digging showed its brilliance, says **Graham Lawton**

Graham Lawton is a staff writer at *New Scientist* and author of *Mustn't Grumble: The surprising science of everyday ailments*. You can follow him @grahamlawton

Graham's week

What I'm reading
A novel called Gould's Book of Fish *by Richard Flanagan. It caught my eye in a charity shop. £2.50 well spent.*

What I'm watching
Wolf Hall: The mirror and the light *on the BBC.*

What I'm working on
Ending my aversion to putting food waste in the dustbin.

This column appears monthly. Up next week: Annalee Newitz

A FEW years ago, I spent an interesting if pungent day visiting two of Europe's most advanced waste processing facilities, a state-of-the-art rubbish dump near Espoo in Finland and a power station in nearby Vantaa. Together, they are playing a pivotal role in greater Helsinki's push towards a circular economy, ensuring that every scrap of the city's municipal waste is either recycled or turned into energy or heat, so nothing is sent to landfill. I remember thinking, "How brilliant, I wish we could do that".

It turns out we in the UK can, and are. But it took me a bit of legwork, and some frustration, to find that out.

Mixed municipal waste, as rubbish discarded by the general public is technically known, is a big mess. Global production is around 2 billion tonnes a year and is projected to rise to 3.4 billion tonnes by 2050. That's about 10 per cent of all waste, and hence a major contributor to the pollution crisis that is engulfing the world.

After Finland, I was a bit obsessed with cleaning up my own contribution to this problem. I was already a diligent recycler, but still discarded a lot of non-recyclable waste, mostly plastic. But with a bit of effort, I found a place to take it. Most weeks, my general refuse bag, which I assumed went to landfill, was empty.

Then I moved to York and was shocked by what I assumed was a substandard waste system. Glass, cans, cardboard, paper and plastic bottles go into shared recycling containers, yet everything else, even food waste, goes in the bin. I tried taking my non-recyclable plastic to the recycling centre, but was pointed to a bin labelled "waste-to-energy" into which a couple were hefting an old carpet. Unsure what that meant, I took it home and left it in the garage.

I was especially perturbed by the absence of food waste recycling: years of living in a part of London with strict rules on the disposal of biodegradables have made me averse to dropping tea bags or vegetable peelings into the general rubbish. So I religiously collected all my organic waste and took it to a local community garden with a compost bin.

I won't be doing that anymore. Not because it is too much of a chore, but because I don't need to. When I dug into how my new city deals with its waste, I found I am basically living my Finnish dream.

> **"I was pointed to a bin labelled 'waste-to-energy', into which a couple were hefting an old carpet"**

Everything that goes in my bin ends up at a place called Allerton Waste Recovery Park, which meticulously sorts it into separate waste streams using a variety of smart technologies and some manual labour. Everything recyclable is recycled. Everything biodegradable is sent to an anaerobic digester and converted into biogas. Everything else is burned to generate electricity, enough to power 66,000 homes. The flue gases from this waste-to-energy incinerator are scrubbed clean of particulates and toxic gases. The final residue, ash, is used in construction materials. Almost everything gets recycled or reused. North Yorkshire Council says that since Allerton opened in 2018, the amount of rubbish going to landfill has fallen by 90 per cent.

You may have spotted the catch: burning trash generates carbon dioxide that is vented into the atmosphere. A 2023 report by the council found that Allerton had emitted almost 300,000 tonnes of CO_2 in the past year. There's also the fact that the incinerated waste – such as the carpet tossed in the skip – took natural resources and energy to produce in the first place. Burning it for energy is essentially the same as extracting fossil fuels and burning them.

Still, in a straight fight between waste-to-energy and landfill, the former is by far the lesser of two evils. The same report says that putting the trash into landfill would have emitted 25 times as much greenhouse gas.

Allerton is part of a largely unsung movement gradually consigning landfill to the rubbish dump of history. It is one of 329 waste-to-energy plants in the UK that collectively consume about half of the 24.5 million tonnes of household and other municipal waste we generate each year. Most of the rest is recycled; only 7 per cent goes to landfill. That's a huge turnaround from the early 2000s when almost all our waste went to landfill.

This is a global trend – according to research and advocacy group Transnational Institute, the size of the waste-to-energy industry is forecast to double over the next decade. At the same time, the technology for converting waste into energy without emitting carbon is improving; Allerton has plans to go carbon neutral.

The fact this is all happening under the radar is a good thing. Putting the onus on ordinary people to solve the waste crisis doesn't work; even in eco-minded Helsinki, household recycling rates are low. We just need this stuff to happen for us; for once, it seems it is. Sorry, community garden, my food waste is going in the bin from now on.

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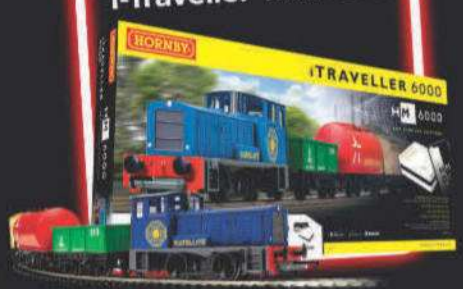

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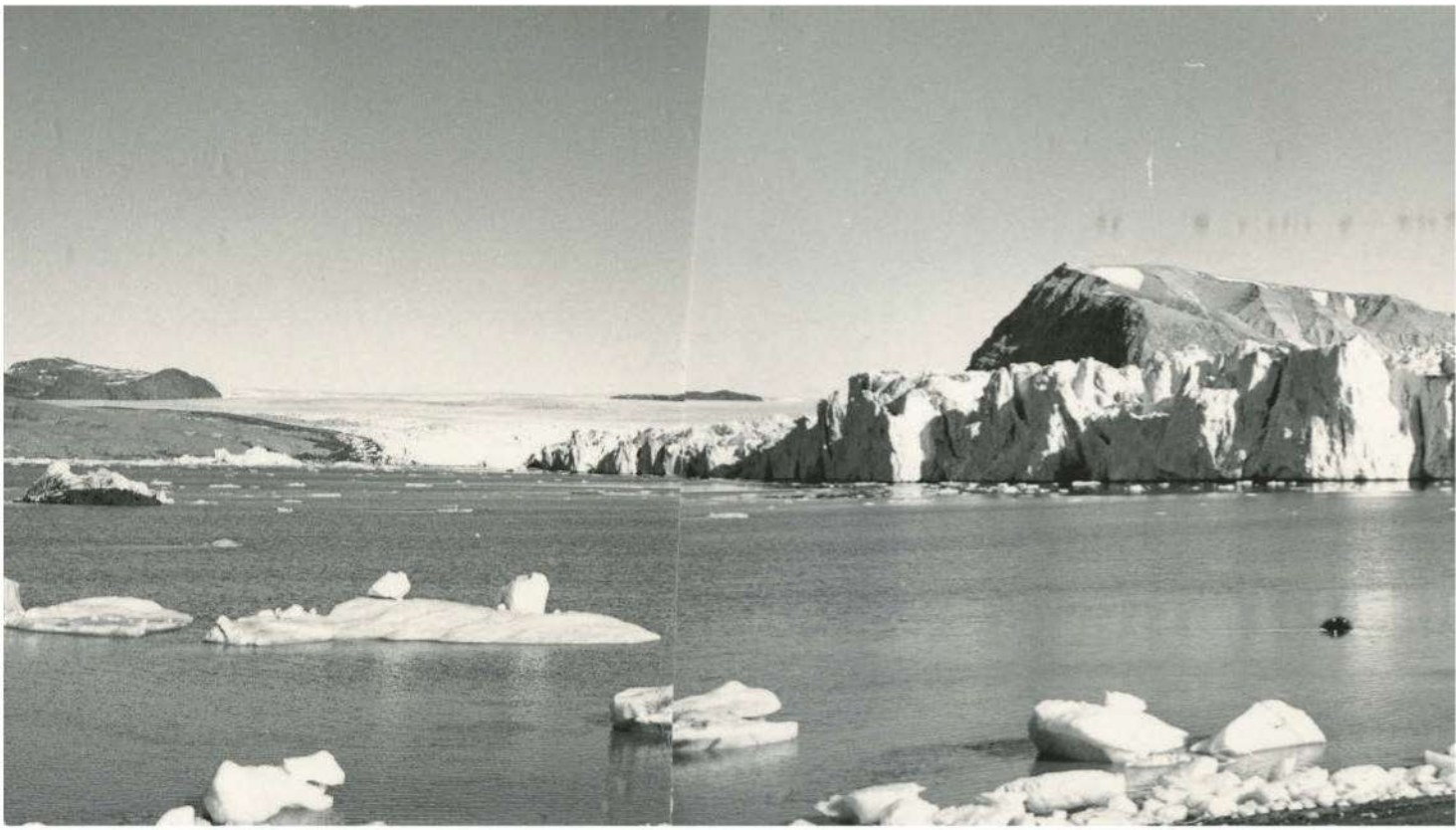

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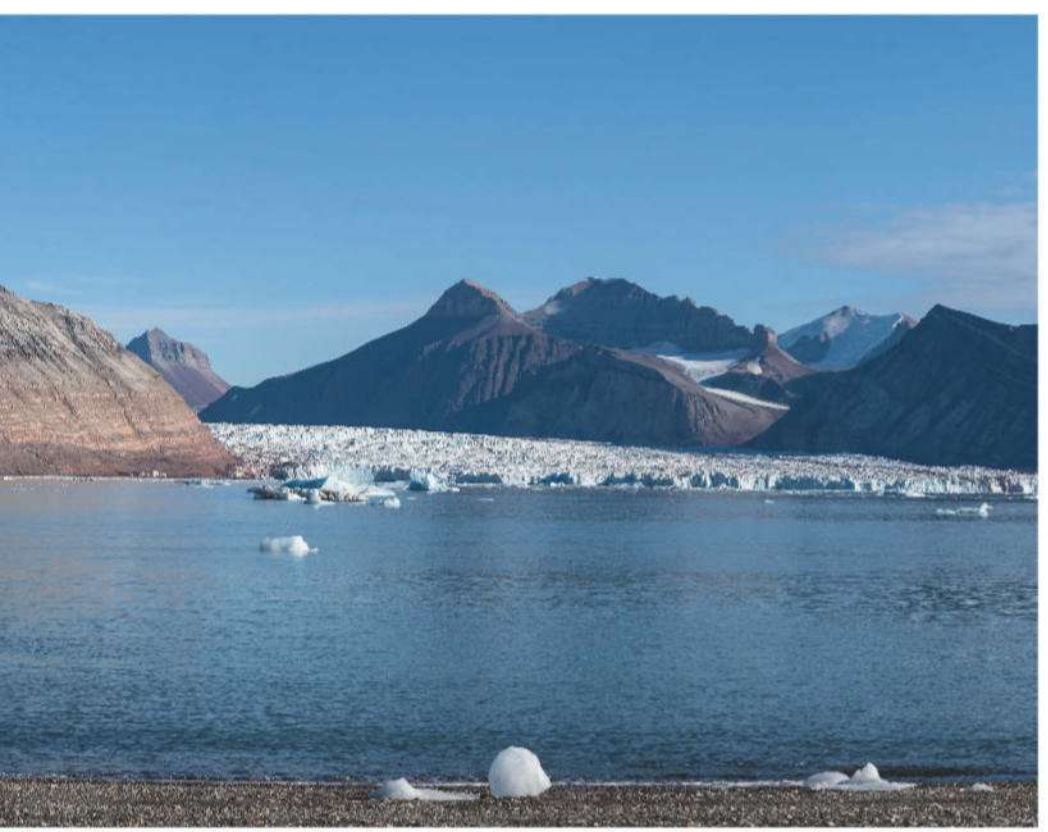

Vanishing act

Photographer **Christian Åslund**
Greenpeace

THE mighty collision of two glaciers – Kongsbreen and Kronebreen – in Svalbard, Norway, is captured in a woven patchwork of black and white images taken by the Norwegian Polar Institute in 1967 (top). Nearly six decades later, a striking panorama of the same site reveals the dramatic ice loss in the Arctic due to climate change (bottom).

"It was difficult to witness because it was such a stark change from the archive photos," says Christian Åslund, the photographer who captured the most recent shot of the two glaciers. "You get a sense of how it has been and how it should be – it's a completely different landscape now."

The sharp contrast between the two panoramas demonstrates the disproportionate impact of rising temperatures in the Arctic. The region is warming more than twice as quickly as the rest of the planet in a phenomenon called Arctic amplification. This is largely due to the loss of sea ice, which becomes increasingly vulnerable to melting as it continues to dwindle. This August was the warmest ever recorded in the Svalbard region, says Åslund.

"I hope these photos serve as a reminder for people that we can all do something to collectively try to turn this tide around," says Åslund. "We have a global responsibility to slow climate change. I don't think it is too late."

Chen Ly

Editor's pick

If only animals could talk? They already can, sort of

2 November, p 21

From Marc Bekoff, Boulder, Colorado, US

Chris Sherwood's excellent piece on animal communication, "If only they could talk", reminded me of an essay I wrote for *New Scientist* more than 30 years ago (21 May 1994) headlined "Why can't we talk to the animals?". Even way back then, we and other animals could "talk" with one another using visual signals, sounds, scents and various combinations thereof.

Sherwood also considers what artificial intelligence might tell us about what animals want and need from us and that we might not like what we learn. While AI might fill in some of the gaps in understanding, we already know – and have known for many decades – that we must treat other animals with much more respect and dignity.

When I updated the second edition of my book, *The Emotional Lives of Animals* (April 2024), I kept track of the 300 or so references and notes I added to the first edition (2007) and not a single one led to the conclusion that we are now doing enough for non-humans. Sherwood is right on the mark that companion dogs with squished faces might tell us they don't like being unable to breathe, but we already know that.

AI may be the icing on the cake for communication with animals, but it won't be the panacea some imagine. All we need to do now is "watch" carefully with our eyes, ears, noses and hearts and we will know when we have crossed the line.

From Ros Groves, Watford, Hertfordshire, UK

While it would be fascinating to decode the messages that lie behind a cat's purr, a dog's bark or the clucking of a rather overfed chicken, I think we have to be aware of our strong instinct to attribute human qualities to these creatures. While they undoubtedly display intelligence, it is expressed in a way appropriate to the confines of their own exclusive domain.

With physiologies and lifestyles so diverse and so very different to ours, we can't begin to expect them to convey, or for us to understand, their emotional states in human terms to any great depth or accuracy. Bees are reported to have been seen "playing" with balls. Yet what would "playing" feel like to a bee?

The AI research will hopefully provide us with some valuable insights into animal behaviour. It is essential, though, to not let our natural anthropomorphic tendencies lead us to believe that this will somehow transform our understanding of and communication with animals into something akin to Dr Dolittle.

On diet: There just aren't enough fish in the sea

2 November, p 32

From Sam Edge, Ringwood, Hampshire, UK

Your articles on nutrition brought several strands of information together nicely, although, as with previous round-ups of this, it seems to sum up as "more fibre, less red meat and sugar, more variety".

One theme that I would like to add is that those of us in affluent societies are now encouraged more than ever to consider the food we eat as entertainment and as being an indicator of our chosen lifestyles, rather than as simple metabolic input. The plethora of instructional and competitive cookery shows on TV, which are endlessly rehashed in other media, is indicative and probably causal of this change.

On a separate note, one thing I wish would stop is the recommending of oily fish. We simply don't have enough in the sea for all of us to eat more fish, and the environmental impact if produced via trawling – or, worse still, via farming – is untenable. I want suggestions of more sustainable sources for the nutrients they contain, such as various beans and squashes.

How much energy was used to find new prime?

2 November, p 19

From Steve Lonsdale, Maxey, Cambridgeshire, UK

Good to hear that the largest-known prime number has been found – but at what cost in terms of energy consumption? Rather than rewarding the finder with $3000, perhaps that money would be better spent on carbon offsetting.

The idea of classical reality has long been upended

12 October, p 40, and Letters, 2 November

From Dave Rowsell, Gowerton, Swansea, UK

I agree with Daniele Oriti that "we have to embrace the fact that we make reality", and note readers' responses. We need to keep in mind that relativity and quantum physics have comprehensively undermined our classical, or Newtonian, view of reality.

For instance, we seem to be increasingly understanding space-time as emergent, rather than some given backdrop to the "things" around us, including you and me. Maybe, too, we should examine what we mean by "objectivity".

Could it be that each of us is, in some sense, the entire universe aware of itself, and that we are all (animals and possibly plants as well) in some kind of quantum superposition with one another? Answers on a postcard please.

End of Neanderthals sounds a bit like war

12 October, p 36

From Dan Conine, Robins, Iowa, US

Your story on how the Neanderthals really died amid the rise of *Homo sapiens*, based on regional occupation, sounds like a perpetual hunt/war between the two groups. It would have started with Neanderthals hunting invasive "weak" humans until our species got smarter and tried to eliminate them.

Those Neanderthals that split off to avoid us survived with some trading of territory over millennia. Maybe some enlightened *H. sapiens* even tried to "save the Neanderthals" in parks (look for them in human burial areas). As Neanderthals were too intelligent to be domesticated, it was easier to enslave our fellow humans. But Neanderthals died off because they weren't ultimately useful in the human artificial environment or, in the end, because they tasted good and were easy to find.

For the record

Despite its name, Barnard's star isn't in Barnard's galaxy (26 October, p 26).

A new type of energy storage device that could be used on Mars is a supercapacitor (2 November, p 12).

In our look at precision nutrition, we misattributed a quote to Regan Bailey (2 November, p 38).

The image used in our look at the effects of sugar rationing was taken in the US, not the UK (9 November, p 14).

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Is this a menu for change?

Vaclav Smil's "big numbers" take on feeding future populations fails to address how global warming will affect food production, says **Michael Le Page**

Book
How to Feed the World
Vaclav Smil
Penguin Books

WE HAD better hope that Vaclav Smil is wrong about the world's food system. If he is right, the implication is that we will end up bulldozing what little remains of nature to keep the food we like on our plates.

The message I took from his new book, *How to Feed the World: A factful guide*, is that the food system pretty much has to be the way it is, and that there will be no big revolutions in food production or in what we eat. With continued, gradual improvements, however, we will be able to keep producing enough food for a growing population in the coming decades.

As Smil explains: "There are too many exaggerated expectations for new, radical 'solutions' in the modern world – it is gradual gains that will matter more." Maybe he is right. But it is one thing to say that things couldn't be different and quite another to prove it.

What's more, if you think the answer to the food and environment crisis is more of the same plus "the power of incremental changes", then it matters if the same will remain possible. For me, this book's biggest flaw is that it fails to address the numerous ways in which global warming is going to affect food production, from extreme weather devastating crops to ocean acidification reducing yields on shellfish farms.

In the introduction, Smil declares he isn't going to cover the "fashionable" topic of climate change, implying that enough books have already been written on this. Is there a reason why this topic is so trendy, I wonder?

The book has too many of these pompous statements for my taste. For instance, Smil emphasises how his book is packed with numbers because, without them, "you will make incorrect interpretations".

Yes, but having the right numbers put in context matters more than having lots of numbers. Take the part where Smil looks at how much fishmeal and fish oil from wild fish is required to produce farmed fish. He cites numbers that suggest fish farming is becoming more efficient and seems to say we could produce more farmed fish while reducing the environmental impact.

"Smil uses the numbers to show why the idea that organic farming could feed the world is 'a load of excrement'"

Back in October, however, I heard a radically different story from Patricia Majluf at the non-profit group Oceana. Her team estimated that the number of wild fish killed for fishmeal and fish oil to feed farmed fish is up to three times higher than previous estimates.

Furthermore, global warming will have a huge impact on fish oil production, Majluf told me. In warmer waters, algae produce less of the vital omega-3 oils that end up in fish oil, and fish have a lower fat content. "So you need to catch a lot more fish to produce the same amount of fish oil," she said. "And there's not going to be a lot more fish." Nor does raising farmed fish on plant-based feeds solve the problem, as crop farming is also far from sustainable.

To be fair, there is a lot of good stuff in this book. Smil uses the numbers to show how we underestimate both the economic importance of food and how much energy it takes to get it onto our plates, why the idea that organic farming could feed the world is "a load of excrement" and why scaling up the production of cultured meat will be so difficult.

But, overall, this book is more about how the world is fed now than how to feed it in the future. And on a rapidly warming planet, I fear gradual gains in food production will, sooner or later, fail to keep pace with accelerating losses. That's why we had all better hope Smil is wrong about the lack of possibility for big change.

In particular, he acknowledges the "impressive" potential for radical yield gains from genetic modification, but then dismisses it as something that isn't likely to happen soon. Perhaps. But new gene-editing techniques are not only much more powerful than older methods, they are also being treated differently by regulators, meaning gene-edited foods are reaching the market much faster.

Yet despite the extraordinary importance of the task, there is still surprisingly little investment in developing better crops for a warming world.

For me, the take-home message shouldn't be that we can't rely on revolutions in how we produce food. Rather, we need to do whatever it takes to make revolutions happen.

Are fish farms like this one in Greece truly becoming more efficient?

ELENA_ALEX_FERNS/ALAMY

Putting death on ice

Could brain freezing cure all disease – indirectly? **Jonathan R. Goodman** explores a book with a bold take on dying

Book

The Future Loves You
Ariel Zeleznikow-Johnston
Penguin, 28 November

MUCH of medicine today focuses on extending life by no more than several months. Drugs for cancer and Alzheimer's disease that are touted for their effectiveness often do little more than give people a bit more time. What if we could send terminally ill people forward to be saved by the medicine of the future, asks Ariel Zeleznikow-Johnston.

It is an interesting question, and one that Zeleznikow-Johnston, a neuroscientist, poses in his book, *The Future Loves You: How and why we should abolish death*. If possible, shouldn't we focus efforts on technologies to help us preserve sick people until they can be cured?

The author takes us through a wide literature, ranging from the philosophy of mind and personal identity to sociology and economics, that he uses to justify his belief that brain preservation is viable and an indirect path to curing all disease.

He defends a new notion of death as an irrevocable loss of identity rather than a permanent cessation of a heartbeat. To him, humans are their neurological connections, what neuroscientists call the connectome. To save or copy this is therefore to save the person.

He also backs the philosophical view that consciousness has more to do with how something functions than with mechanisms underlying those functions: if something acts in a way that is indistinguishable from you, it is you. This view, known as functionalism, is popular among people working in technology who want to make claims about the consciousness of machines.

Next, we have an interesting explanation of the neuroscientific advances needed for effective connectome preservation. He says we can use novel techniques relying on a process called vitrification to prevent damage to brain cells when freezing them.

JESSE RIESER/THE NEW YORK TIMES/REDUX/EYEVINE

Checking on patients at the Alcor Life Extension Foundation in Scottsdale, Arizona

Preserving the brain – or finding a way to copy its synaptic connections – would be enough for him, given his philosophical leanings, to say we have preserved the connectome.

Amid all this, he defends the idea that people of the future must love us: they owe us for their existence, he says, just as we owe the people of the past for giving us our world today. People of the future will therefore owe it to us to wake us up from our preserved states and cure whatever diseases we may have.

If these arguments sound too broad to be plausible, it is because they are. The further you read, the more Zeleznikow-Johnston seems to ask for intellectual blank cheques to fund research. Defining death as a loss of personal identity? A functionalist view of consciousness? Ethics, economics, sociological effects of preservation? Blank cheques the lot.

There is, in fact, little the author doesn't ask us to take his word for – before comparing himself to Gottfried Leibniz, the 17th-century polymath who first envisioned, among other things, what a computer might look like.

The worst of this is his dismissal of the sociological implications of life preservation. Billionaires spend huge amounts on life extension, and whether extending some people's lives will increase inequality isn't an issue he considers for more than a few paragraphs.

In the early pages, Zeleznikow-Johnston lambasts philosophers for saying people should accept death as an inevitability, and says they therefore aren't seeing the world as it "truly" is. Yet his dismissing their work to defend a view he has already formed about humanity, death and the future isn't an effective refutation.

Modern medicine isn't perfect, and Zeleznikow-Johnston poses important questions in his book. But as a defence of a new position, it falls short of world-changing.

Jonathan R. Goodman is a writer and researcher at the University of Cambridge

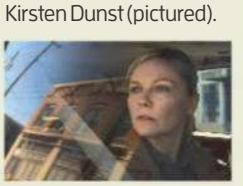
New Scientist *recommends*

Jeremy Hsu
Reporter
New York

Anyone who enjoys strategising over puzzles as a team will find a lot to like in **Sammu-ramat**, a cooperative board game challenging up to five people to help the legendary Sammu-ramat fend off threats to the Neo-Assyrian empire. Players can draw on a diverse array of royal advisers with special abilities, such as an Egyptian priestess with healing powers and a spy who can pass speedily and stealthily through enemy territory.

My friends and I barely managed to win before invading enemy armies or a spreading plague overwhelmed us. But even if your empire crumbles, you can pick up the pieces and try again.

I also watched **Civil War**, a film set in a US riven by conflict, starring actors including Kirsten Dunst (pictured).



A24

I delayed viewing what seemed a fraught choice during the tempestuous election cycle. The film's foreboding and surreal vignettes, which show what happens when leaders and ordinary people embrace violence to solve political division, are particularly ominous.

The sci-fi column

Hard stuff In *Lake of Darkness*, two deep-space science ships meet to study a black hole. Their research comes to an abrupt halt, however, when crew members start dying horribly in this bold, experimental novel, says **Emily H. Wilson**

Emily H. Wilson is a former editor of *New Scientist* and the author of the *Sumerians* trilogy, set in ancient Mesopotamia. The second book in the series, *Gilgamesh*, is out now. You can find her at emilyhwilson.com, or follow her on X @emilyhwilson and Instagram @emilyhwilson1

Book

Lake of Darkness

Adam Roberts

Gollancz

Emily also recommends...

Book

Exodus: The Archimedes engine

Peter F. Hamilton

Tor

While I am talking about hard sci-fi, it would be remiss of me not to mention Peter F. Hamilton, given that he is arguably the reigning king of the subgenre. His new book, the first in a duology, is linked to an upcoming computer game. The computer game bit isn't a selling point for me, but I have made a start on the book and so far it is full of trademark Hamilton big ideas.

LIUZISHAN/GETTY IMAGES

Something evil may be lurking in a black hole in Adam Roberts's new novel

I WAS recently asked for my definition of "hard science fiction" and I burbled something along the lines of "it has to have a lot of science in it, and also spaceships". I'm not sure the spaceships bit is right. But if, for the sake of this article, my terrible definition is the one in play, then *Lake of Darkness* by Adam Roberts hits the mark 100 per cent.

In this case, the spaceships are two deep-space science vessels, which convene at a black hole in order to study it. This is in a far future where humans inhabit a post-scarcity galaxy. It is a bit like the world of Iain M. Banks's *Culture* novels, except that in this universe, no other intelligent life forms have (so far) been discovered and artificial intelligence hasn't reached *Culture*-level heights.

Alpha Raine, the captain of one of the ships, starts to think he is communicating with something inside the black hole. Even though it should be impossible, shouldn't it? Could an alien life form – a "blackholer", you might call it – be communicating via something called Hawking radiation?

You may guess that this hard sci-fi novel covers black hole science in quite some detail. In fact, it features a vast swathe of theoretical physics. However, it is first and foremost a story, and the question of how the blackholer might be communicating with humans is quickly overshadowed,

"Could an alien life form be communicating with a ship's captain via something called Hawking radiation?"

plot-wise, by Raine's decision to slaughter his crew. This he does in increasingly ghastly ways and for no apparent reason. Is something very dangerous, very evil, very ancient and very contagious hiding inside the black hole?

I won't say more in order not to ruin the plot, but I will tell you there is a lot of horror, religion and psychology, plus lots of literary allusions, mixed in with this far-future story of what could possibly be first contact. Possibly.

Roberts has written 25 novels and, at this stage of his career, he is obviously unafraid to play with structure and the expectations of the reader. There is nothing cosy or easy about this novel. The story is told by... we aren't sure who. The action comes to us from the points of view of different people at different times. The characters are atypical heroes in that they are generally downright unappealing. Everyone is apparently quite stupid, or at least they are strangely unaware of the potential threat posed by the blackholer (if it exists).

Sometimes, the characters are drawn as comedically awful, as in the case of one supposed "great brain" called Guunarsonsdottir, such a terrible person that her monologues are laugh-out-loud funny. These humans are increasingly infuriating, having long discussions and insisting on lengthy democratic voting processes even as life-threatening violence is unfolding around them. But then, as I kept on thinking and worrying over, how much of their conduct was being caused by possible infection from the blackholer? This is a book you will wake up thinking about!

By the end, I still hadn't worked out why one important plotline had happened and I couldn't be sure I had understood the ending. That hasn't put me off one bit. The book is intelligent, experimental, grippingly propulsive and full of astonishing ideas. I have read three of Roberts's other books, including *Salt* and *Jack Glass*, all of them superb, innovative and quite startling. I now intend to work my way through the rest of his canon. Here's to hard sci-fi! ▮

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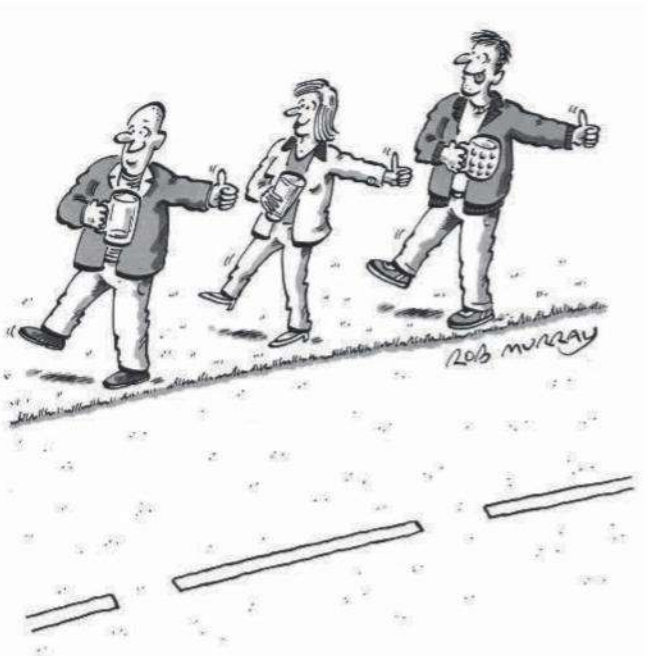

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Volatile cosmology

The universe as we know it could vanish in an instant. What does our continued existence tell us about the reality we can't see, asks **Miriam Frankel**

BILLIONS, perhaps trillions, of years from now, long after the sun has engulfed Earth, cosmologists expect the universe will end. Some wrestle with whether it is more likely to collapse under its weight in a big crunch or keep on expanding forever into an infinitely empty big freeze. Others reckon our cosmic endgame will be decided by a mysterious kind of energy that shatters the universe in a big rip.

But there is a more immediate cataclysm that may already be barrelling towards us at the speed of light: they call it the big slurp.

The slurp in question starts with a quantum fluctuation that sets a bubble rolling across the universe like a cosmic tidal wave, obliterating everything in its path. We should take this possibility seriously, says John Ellis at King's College London. In fact, it is less a matter of if this apocalypse will play out, but when. "It could happen while we're talking," he says.

Theorists like Ellis are actually surprised that such a catastrophe hasn't already occurred in the observable universe. But rather than taking our precarious existence for granted, they are using the plain fact we are still here as a tool. The thinking is that there could be some exotic physics preserving us.

This kind of existential cosmology is even helping physicists filter through their myriad models of the universe, and could tell us how the cosmos began in the first place. "You may need something that stabilises [the universe], and it could be a new physics," says Arttu Rajantie at Imperial College London.

Quantum fields are the fundamental building blocks of the universe, which then give rise to the more familiar particles and forces of the standard model of particle physics. Chief among them is the Higgs field, associated with the Higgs boson, which permeates the universe and gives elementary particles their mass.

The Higgs had been hypothesised for decades, but we were in for a surprise when the particle was finally measured at CERN's Large Hadron Collider (LHC) near Geneva in 2012. The result suggested that the Higgs field isn't stable because it isn't in its lowest possible energy state. We know that objects like atoms or particles tend to want to minimise their energy, so in theory the Higgs could suddenly drop to its lowest possible state in a process known as a phase transition.

This is similar to the phase transition that occurs when liquid water boils to make steam. If you look inside a saucepan of near-boiling water, you will see tiny bubbles of gas nucleating at the bottom. Similarly, a phase transition in the Higgs field would create bubbles of its lowest possible energy.

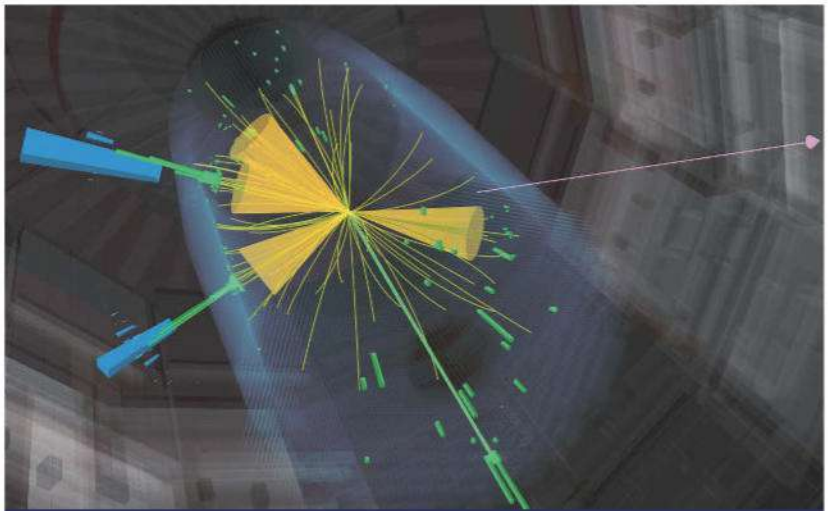
These bubbles would contain very strange physics. As a bubble formed, the quantum fields inside would suddenly shift, effectively rewriting the laws of physics and creating chaos. Terrifyingly, the bubbles would expand at light speed, swallowing everything around them.

Slurp it up

The appearance of this apocalyptic bubble comes down to chance. As an analogy, imagine the Higgs field is a ball at the top of a hill that has several valleys of differing heights beneath it. The ball could roll down into one of the higher valleys and stay there happily, while still not being at the lowest possible point. This is the situation the Higgs field is in now, which we call a "metastable state". A ball in such a valley can't roll out of it without a kick. But because this field conforms to the rules of the quantum world, it can mysteriously "tunnel" to a lower valley, or energy state. This is a quantum process akin to a ghost walking through a wall. We can make estimates for how likely the Higgs field is to do this in a given time period, but we can't predict exactly when it will occur.

The stability of the Higgs field (or the shape of the valleys in our analogy) depends on the complex way that other elementary particles interact with it. Particles called bosons, which carry the fundamental forces, tend to make the field more stable. In contrast, particles known as fermions – the constituents of matter, such as quarks – make the field less stable, raising the risk of a phase transition.

Recent measurements of these particles at the LHC aren't comforting. Aside from the Higgs itself, the heaviest known fundamental particle, called the top quark, has the greatest influence on the stability of the Higgs field. The heavier it is, the less stable the field is. ›



CERN/CMS COLLABORATION

"Our continued existence is an argument for why primordial black holes can't exist"

MAXIMILIEN BRICE/CERN

Measurements of the top quark and the Higgs boson at CERN's Large Hadron Collider suggest that the universe could vanish in an instant

In recent years, as measurements of the top quark mass have become more precise, it has become clearer that the Higgs is – according to the standard model – metastable. "The measurements are now so good that we pretty much know that we are in that metastable range," says Rajantie.

Assuming there's no mistake, the universe is doomed – we just don't know when the big slurp will happen. Based on the shape of these valleys, it is likely to be in billions of years. But it could be tomorrow.

What we do know is that we are still here. That is proving a useful insight for physicists weighing up the many models of the cosmos that proliferate today, says Rajantie. Some invoke unproven entities that could spark a catastrophic phase transition, while others may be keeping us hanging in the balance.

In particular, strong gravitational fields can "seed" the Higgs field, making it more likely to transition sooner rather than in billions of years' time. "When you're boiling water, if there are any impurities in the water, then that's where the bubbles tend to form," says Rajantie. These triggers include cosmic strings and other defects in space-time. Black holes, which are so massive that not even light can escape, are also good candidates to seed the Higgs field and provoke the big slurp.

Provoking disaster

Some black holes are better at seeding than others. In 2014, theorists including Ruth Gregory at King's College London and Ian Moss at Newcastle University, UK, calculated that since smaller black holes have a larger space-time curvature at their outer edge, they are more likely to provoke a phase transition. The gravitational field of these small black holes is concentrated in a tiny point, rather than spread out as in the case of a supermassive black hole. Small black holes "seem a lot more likely to cause the end of the universe", says Moss.

Indeed, it is the tiniest black holes, called primordial black holes, that we should fear the most. Although they have never been directly detected, primordial black holes are often included in cosmological models – added to explain dark matter, for instance, or the origin of supermassive black holes. They are thought to have formed when extremely dense clouds of plasma in the early universe collapsed.

Like all black holes, primordial black holes evaporate by emitting radiation. But the diminutive size of primordial black holes means they emit radiation more quickly and create "hot spots", which have a much higher temperature than the surrounding space. This higher temperature could provoke a phase transition bubble, as the Higgs field is more likely to receive a thermal kick that pushes it out of one valley into a lower, more stable valley, according to research published in September by Lucien Heurtier at King's College London and his colleagues.

In fact, because smaller black holes have stronger gravitational fields at their outer edge, primordial black holes get more dangerous as they evaporate. "It means that the risk for a Higgs phase transition increases with time," says Heurtier. Our continued existence, he says, is an argument for why primordial black holes can't exist and why cosmological models built on them should be scrapped too.

There is, however, an alternative explanation for why the Higgs field hasn't transitioned. Despite the precise measurements of the top quark and the Higgs boson, we can't be certain that the Higgs is in a precarious metastable state after all. It might be that there are unknown particles and forces stabilising the Higgs field in a way that protects us from the big slurp. "If there's some other particle that comes into play at some higher energy, then that will change the story again – we just don't know yet," says Katy Clough at Queen Mary University of London.

For example, a hypothesis called supersymmetry posits that every particle we know of has a much heavier "superpartner", and if these really exist, they would have a stabilising effect on the Higgs field. However, so far, the LHC has failed to find any evidence for these superpartners. "Supersymmetry is one way of avoiding the problem – the Higgs field metastability is a pro-supersymmetry argument," says Ellis. "I retain my enthusiasm for supersymmetry, but I am somewhat disappointed that my love for it hasn't been requited yet."

The alternative, he says, is to resort to

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"special pleading" arguments, whereby most of the cosmos already flopped into its lowest-energy state, but a few regions, such as ours, were left in a metastable state on the brink of collapse. In this view, a metastable state is necessary for life, so we must find ourselves living in one of these precarious patches.

In the absence of direct evidence of new particles, Rajantie thinks we should investigate what we can learn about cosmology if we just assume the Higgs field is metastable. He is using this supposition to weigh in on models of quantum gravity, which seek to unify quantum theory with general relativity, the two central pillars of modern physics.

For example, we don't know exactly how the Higgs field and gravity affect each other in these models. Physicists describe this interaction with a parameter called non-minimal coupling, but it is complicated to determine because the Higgs and gravitational fields are so different in nature. Neither can we measure it, because gravitational fields in the universe today are so weak.

But Rajantie has used our cosmic existential crisis to focus in on the strength of this parameter by eliminating the impossible. We know the parameter can't be negative; if it were, the Higgs field would be so unstable that it would have triggered a phase transition during inflation – a sudden period of rapid expansion early in the universe's history – which clearly didn't happen. And if the parameter is greater than 10, then the phase transition would have been triggered at the end of inflation. "We can say that it must be between 0 and 10 because otherwise the universe would not have survived inflation," says Rajantie. Many current models of quantum gravity are in line with this, he says, suggesting they are on the right track – and any new models put forward must follow suit.

A deeper valley

We should take heart that the big slurp doesn't seem to have occurred in the universe's ancient past. Back then, there was a lot more energy around to kick the Higgs field into a deeper valley, making a phase transition more likely to occur in a given time period, says Rajantie. In that sense, our cosmos making it to the ripe age of 13.8 billion years old is something to celebrate. "Today, it's very difficult to achieve a phase transition due to relatively low energies," he says.

But for this same reason, Rajantie believes a bubble has probably already been created somewhere, just not within our visible universe. "It is incredibly likely that it has already happened in the early universe and it just hasn't reached us yet," he says. Where in the vast expanse of the unobservable universe this might have happened is anyone's guess – leaving us, once again, in the dark about when our time might be up.

Faced with uncertainties like these, existential cosmologists are eagerly awaiting the results of an experiment at the University of Cambridge that Moss and Gregory are involved with. Excitingly, this experiment aims to create a laboratory analogue of a universe phase transition, which could help researchers refine their ideas about what is most likely to cause the big slurp.

That's because the equations describing a quantum phase transition in the universe can, in some circumstances, be equivalent to those describing a phase transition in a kind of strange matter called a Bose-Einstein condensate, which consists of atoms at extremely low temperatures. The latter would also produce bubbles, effectively simulating a cosmic phase transition.

The experiment could even simulate a seeded phase transition, where the seed is an imperfection engineered in the system rather than, say, a real primordial black hole. Researchers would be able to explore the difference in the rates of bubble creation with and without seeds – potentially giving us a better idea of how much danger we are in.

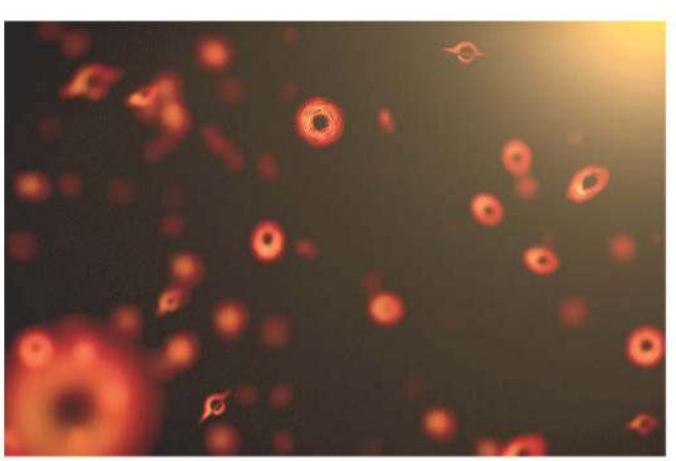
Ultimately, how long we have left may be a matter of luck, says Ellis. Unless, that is, we accidentally provoke the Higgs field to transition in a particle collider experiment on Earth.

In 2019, Moss and Gregory calculated how particle collisions, either from cosmic rays or in experiments like the LHC, could create tiny back holes that seed a phase transition. For their part, they doubt experiments on Earth could push us over the edge, as these kinds of collisions were prevalent in the early universe and, as far as we know, didn't cause it to end.

More research is required to be certain, though, says Moss. For example, when it comes to phase transitions, it is important to consider the area of the particles colliding as well as their energy. "We're fine to collide protons [as we do at the LHC], but we know less about the effects of colliding very large nuclei," he says.

But for all that the end of the universe depends on the whims of the Higgs, we may well owe our existence to it in the first place. Last year, Clough and her colleagues published research suggesting that quantum tunnelling effects could prevent a contracting universe from collapsing in a big crunch. In their model, this contraction squeezes a Higgs-like field in such a way that its lowest-energy state becomes negative. This would cause a collapsing universe to bounce outwards, creating a new, expanding universe perhaps not unlike our own. ▮

"It is incredibly likely that a catastrophic bubble has already happened and it just hasn't reached us yet"



NASA/GODDARD SPACE FLIGHT CENTER

Primordial black holes are among the most likely candidates to seed a bubble that rewrites the laws of physics

Miriam Frankel is a freelance science journalist based in London

Urban hotspots

China's megacities are sizzling, revealing a future many more of us will face – and also some ways to cope, finds **You Xiaoying**

"MY OFFICE felt like a steamer on Monday morning," wrote Chinese influencer Bi Dao in a social media post in August. He fetched a drink from a supposed cold-water dispenser – it was 40.8°C (105°F). Bi, who lives in Hangzhou, a regional capital on China's east coast, decided to roam the city with a temperature gun, pointing it at things to find out exactly how hot they had got. "The ground was 72.6°C, the seat of a sharing bike was 56.5°C, the handrail in the metro station was 45°C, even the tree bark was 38.7°C," he wrote. He ended his post by thanking Willis Carrier for inventing the air conditioner.

Hangzhou is known for its beautiful lake, large pagoda and rolling green tea farms – not for heat. But what Bi witnessed was only one of the 60 "high-temperature days" – ones that topped 35°C (95°F) – that grilled the city and its 12.5 million inhabitants this year. Hangzhou isn't alone. Many cities worldwide are feeling the heat. Things are getting so bad that growing numbers of people face temperatures that are beyond human endurance.

Already, such conditions kill around half a million each year. That will inevitably rise as climate change increases the number and intensity of heatwaves around the globe. Cities are on the front line of this unfolding crisis. And China's vast, densely packed megacities are leading the way. As well as providing a glimpse of what we are in for,

they offer lessons that could help urbanites everywhere adapt, from their "vertical forest cities" to cleverly designed parks – and new, cool building materials.

Many temperature records have been broken this year, with astonishing readings reported worldwide, from Perth in Australia to New Delhi in India. This isn't a flash in the pan. The probability of heat extremes has nearly doubled every 10 years since 1979. And things are getting worse. "In the past decade or so, there has been a tremendous increase in intensity and frequency of heat extremes," says Robert Vautard, who co-chairs a working group at the Intergovernmental Panel on Climate Change. The past northern summer was the hottest on record, with average temperatures between June and August 0.69°C higher than the 1991 to 2020 average for those months. It beat the previous record, set just last year, prompting UN Secretary-General António Guterres to comment that "the era of global boiling has arrived".

According to research published last year, if current climate policies continue, a third of the world's population will live outside of a safe temperature range by the end of this century. The study looked at the "human climate niche" – the temperature range most suitable for our survival (see "Deadly heat", page 38). "We project that every 0.1°C of further global warming will expose around 100 million people to extreme heat risks. That is a major concern," says one of the researchers, Tim Lenton at the University of Exeter, UK.

Urbanites will bear the brunt because cities suffer what is known as the urban heat island effect. This is a result of having less vegetation – which can counter heat – than rural areas and many buildings, pavements and roads that absorb sunlight and radiate heat. "The experience of heat in cities is very different from heat in the countryside," says Eric Mackres at the World Resources Institute's cities programme. "Think about the way it feels to stand on a hot, unshaded pavement with no breeze and the sun beating down on you."

Cities are already home to over half of us and by 2050 nearly 7 in 10 people are projected to be urbanites. This exodus from the countryside is especially pronounced in China, where the shift to city dwelling has exposed an extra 115 million people to extreme heat over the past two decades. By mid-century, the population experiencing heatwaves there is projected to jump by as much as 12-fold .

To put things into context, the Yangtze River Delta region in the east of China, which includes the enormous cities of Hangzhou, Shanghai and Nanjing, is now one of the world's largest urban clusters. One-and-a-half times the size of the UK and home to 220 million people, this region baked in record-breaking heat for more than two weeks straight from the end of July this year, earning it the nickname China's "oven". Summers also happen to be humid in many of the nation's economic hubs – including Shanghai, Chongqing and Hong Kong – due to the monsoon climate. Humidity compounds extreme temperatures because it becomes harder for people to sweat.

Record-breaking summer

Across China, this past summer was a taster of what is to come. Relentless waves of extreme weather scorched many places for weeks on end, leading to a barrage of heat warnings and broken records. July was the hottest month ever seen in China. But as early as mid-June, temperatures in the capital, Beijing, were already pushing 40°C (104°F). Crossing the city's notoriously wide roads in the sun became a physically demanding mission, even for the young and healthy. Iron-willed tourists on Tiananmen Square equipped themselves with sunglasses, parasols and anti-UV face masks as they admired the country's political heart in the heat of the day. Increasingly, ›

LUKYEEE1976/GETTY IMAGES

Humidity makes Shanghai's heat more unbearable

people wear portable air conditioners around their necks.

"Frequent extreme heatwaves have arrived earlier than we had expected, and their intensity is getting stronger and stronger every year," says Xu Chi at Nanjing University. Summers are also lasting longer. On 22 August this year – a day that should have been *chu shu*, meaning "the end of heat", according to China's traditional season calendar – another regional capital, Chengdu, issued a red alert for a heatwave. During the week to follow, the city of 21 million in the south-west experienced power shortages due to surging electricity demand driven by the use of air conditioners.

In China and beyond, exposure to excessive urban heat is, in many ways, an issue of social justice. Vulnerable groups ranging from low-income communities to the elderly are expected to be disproportionately affected. For example, those who toil outdoors will probably lose significant working hours as extreme heat becomes more and more frequent. "The same heatwave is not the same for all people, such as those with pre-existing conditions or living in certain types of buildings or maybe buildings without air conditioning," says Weng Qihao at the Hong Kong Polytechnic University. And, globally, the countries most affected by extreme heat are often those with lower and middle incomes: research indicates that the five with the highest numbers of people at risk of exposure are India, Nigeria, Indonesia, the Philippines and Pakistan.

Yet, we have been slow to react to the growing threat, perhaps because heat is an invisible killer. The first thing cities should do, according to Vautard, is "prepare for temperatures that are much higher than current extreme ones". For Wang Yujia at the University of Nebraska-Lincoln, a crucial aspect of this is to improve the outdoor environment. "There's a big difference between a city being survivable and a city being livable," he says. "The question is how do we make sure that, in the face of the rising heat, we still maintain the same quality of living where people, especially children, can go out there and enjoy their time in the outdoors."

> "Exposure to urban heat is, in many ways, an issue of social justice"

One answer is trees. Research shows that they can cool the surface temperature of cities by up to 12°C (22°F). And creating urban forests within 1 kilometre of residential areas is the most effective way to reduce heat-related deaths, according to a new study by Song Jinglu at Xi'an Jiaotong-Liverpool University in Suzhou, China, and her colleagues. She hopes this finding will guide planners in compact cities to identify suitable spots for such planting.

Trees are already being used to remarkable effect in Nanchang, an industrial city and the capital of the landlocked Jiangxi province in south-east China. Its Fish Tail Park is a 51-hectare wetland featuring dozens of wooded islands on a lake. Completed in 2021, it was built by a team led by Yu Kongjian, the brains behind "sponge cities" that can mitigate excess

WANG YUELING/XINHUA/ALAMY

Tourists braving the heat in Beijing's Tiananmen Square

Deadly heat

The combined effect of heat and relative humidity can be gauged using a "sweating" thermometer: one wrapped in a damp cloth that allows you to get a reading known as a wet bulb temperature (WBT). This is more realistic in terms of how our bodies cope with heat because high humidity reduces or even stops the ability to sweat and stay cool naturally. Using this method, research published in 2010 concluded that the limit of human survival is a WBT of 35°C (95°F) – equivalent to an ambient temperature of 35°C and 100 per cent humidity or 40°C (104°F) and 75 per cent humidity. Above this, even a healthy person in the shade won't live longer than 6 hours, with overheating resulting in heat stress, a leading cause of weather-related deaths.

In fact, our tolerance to humid heat may be even lower. In 2022, a study looked at how people reacted to heat in real life and suggested the survival limit at 100 per cent humidity is between 30°C (86°F) and 31°C (88°F) WBT. Weng Qihao at the Hong Kong Polytechnic University says that, in such highly humid conditions, even 28°C (82°F) WBT can lead to severe strain and heat stroke. In a recent paper, Weng and his colleagues concluded that most existing measures to define heatwaves fail to capture the danger to humans because they aren't applicable to all regions and climate conditions. He is calling on scientists to develop a global framework for better assessing these aspects of heatwaves.

water, as part of the national flood-control programme. It has since become a go-to place for the city's 6.2 million residents seeking refuge in its notoriously humid summers.

There is good reason for the park's popularity. Average temperatures on its forested islands are between 2 and 4.6 per cent cooler than in the surrounding streets. "It's a unique piece of urban ecological park," says Wang, who made these measurements with his colleagues in summer 2023. Because it was built as a sponge city park, its elevation is lower than the surrounding urban areas, a feature that doesn't just let water drain away, but also allows cooler air to circulate. "You get lower temperature and increased wind," says Wang.

STEFANO BOERI ARCHITETTI

TURENSCAPE

A vertical forest city block (left). Trees in Fish Tail Park (below)

Going greener

Other Chinese cities have adopted a variety of initiatives to boost their greenery. Shenzhen, a city of more than 17 million in the south, for example, is promoting plant-abundant "green roofs". These can lower ambient urban temperatures by around 1°C (2°F) and slash the electricity demand associated with cooling by 8 per cent. And in the province of Guangxi in southern China, a "vertical forest city" is being built in Liuzhou, featuring high-rise blocks planted with thousands of trees and shrubs.

Increasing urban green spaces is a "highly effective way" for cities to adapt to extreme heat, says Lenton. It has the added benefits of offsetting carbon emissions and improving well-being. And it is relatively cheap. "There needs to be targeted investment in increasing green space in the global south and especially the poorer parts of cities," he says.

When it comes to cooling indoor spaces, there is another cheap, low-tech solution: "cool roofs" – ones painted white or covered with certain materials, such as light-coloured gravel, to reflect sunlight. "There's no real cost to it because the materials used for traditional cool roofs are no more expensive than a typical roof," says Aaswath Raman at the University of California, Los Angeles. But the benefits are substantial. A cool roof can lower temperatures inside a home lacking air conditioning by up to 3.3°C (6°F). In one with air conditioning, it can reduce the amount of cooling needed to keep the space at a comfortable temperature by between 11 and 27 per cent. This is a double positive because air conditioners belch waste heat into the outside air, making cities around 20 per cent hotter during heatwaves, and they are also responsible for around 20 per cent of the total electricity used in buildings worldwide. Demand for air conditioning is expected to more than triple by 2050, a big worry given that burning fossil fuels is still the primary means to generate power.

> "We have been slow to react, perhaps because heat is an invisible killer"

"Unless all the energy driving air conditioning is clean, you're going to have this feedback loop. Hotter temperatures mean more air conditioner use, which means more carbon emissions," says Raman. He and his colleagues are attempting to curb this vicious circle – and provide ways to make indoor spaces more comfortable for people who can't afford air conditioning – by developing materials that can cool buildings without using electricity. It began a decade ago, with the invention of a multi-layer material that remains cold even in direct sunlight because it radiates heat at a wavelength that can escape straight into space without being captured by the atmosphere. Since then, Raman has co-founded a company called SkyCool Systems to develop a series of other cooling materials. These include a film that can be applied to roofs and outdoor structures and a panel that improves the efficiency of refrigerators.

Raman believes a lot can be done to buildings and outdoor spaces to combat heatwaves – for example, creating cold surfaces near people waiting for a bus. "We are thinking about how this could be used in lower-income countries that don't have good insulation in a lot of buildings," he says. He has even found that a layer of metallised polypropylene would help windows and walls reflect more heat – it is the stuff used to make crisp packets. "You could imagine retrofitting facades with recycled potato chip bags," he says.

Other experts say what is needed most – at least in the short term – are administrative measures to deal with excessive heat. "This can involve immediate actions during a heatwave like rescheduling school and work hours or setting up areas where the public can access drinking water, escape the heat and, if necessary, get medical attention," says Clair Barnes at Imperial College London.

Authorities in Hangzhou are clearly aware of this. In August, as the heat became unbearable, the city's government opened cool, underground air-raid shelters, capable of holding thousands of people, providing free cold tea, Wi-Fi and ping-pong tables. Apparently, the measure proved to be a hit. ▮

You Xiaoying is a freelance climate writer based in London

“It’s not football any more”

The controversies surrounding football’s video assistant referee system highlight our troubled relationship with uncertainty and the limits of rationality, says **Daisy Christodoulou**

ALEX DODD - CAMERASPORT VIA GETTY IMAGES

Liverpool fans jostle for a look at the on-field VAR screen at Anfield stadium

IF YOU have watched any football – or soccer – over the past few years, you will know that the game has been consumed by controversies over its new refereeing technology. The video assistant referee (VAR) system was introduced to the English Premier League in 2019 to reduce refereeing errors. Instead, it has created new kinds of uncertainty and undermined our understanding of fundamental rules like offside and handball. It has also infuriated fans, who can often be heard chanting "it's not football any more" after a long-winded VAR check.

It is fair to say that football fans like to get irate, especially when refereeing decisions go against their team. But as I argue in my new book, *I Can't Stop Thinking About VAR*, there is more to this than meets the eye. As someone whose job involves developing new methods of measuring educational attainment, I have thought long and hard about the reasons why VAR has been so frustrating. I believe its problems relate to the challenge of pinning down objective reality, the difficulty of precise measurement and our dislike of uncertainty.

What I have also come to realise, however, is that VAR exemplifies the limits of rationality in many walks of life far beyond the football field. As such, a brief exploration of the history of measurement more broadly – from attempts to pin down the boiling point of water in the 18th century to the struggle to accurately assess the risks of new drug treatments today – can shed light on what really underlies the problems with VAR and how to solve them.

One major issue with VAR is the assumption that more scrutiny is always a good thing because it will provide us with a more objective understanding of reality. A lot of the time, however, greater scrutiny just adds confusion and complication.

VAR reviews often involve an off-field referee poring over a video replay and disagreeing with the on-field referee who saw the incident in real time. We don't always hear the deliberations, but it is clear that the off-field referee sometimes simply has a different interpretation of events to the on-field one. In this case, the legitimacy of the on-field referee has been undermined, but their decision hasn't been replaced with a more objective one: the subjectivity has simply doubled. Far from removing arbitrary human judgement, VAR emphasises just how arbitrary it is.

Occasionally, the slow-motion replay allows the video referee to see things that the on-field referee missed. But every so often, the things the on-field referee failed to spot were also missed by all the players and fans as well, and if we change decisions based on previously unnoticed aspects of reality, then we are going to have a completely different game. In that sense, the fans chanting "it's not football any more" have a point.

Take offside decisions, which have always been some of the trickiest. A player is offside if, at the moment the ball is played to them, they are in the opponent's half, ahead of the ball and ahead of the penultimate defender. This rule requires a human official to look at at least three things at once: the player kicking the ball, the penultimate defender and the player receiving the ball. Of course, this is impossible, which is why the pre-VAR game saw so many errors.

It seemed obvious that technology would fix this problem, because video replays allow us to look at multiple things at once. But VAR's offside decisions are also wildly contentious, with fans and players outraged by marginal offsides for stray toenails and armpits. Clearly, you have to draw the line somewhere, but ›

"VAR has made people realise that accuracy isn't the only virtue"

PREMIER LEAGUE

JULIAN FINNEY/GETTY IMAGES

the problem is that VAR picks up offsides that would never have been spotted before. Although these marginal decisions might be correct according to the letter of the law, they aren't in keeping with its original intention, which is to stop attackers camping out permanently in the opposition penalty box and having long balls pumped up to them. This means that, while VAR may be giving us a clearer picture of reality, it isn't a reality we are happy with.

Another complaint is about the accuracy of offside decisions. After all, if you are going to claim that players' toenails are offside, your measurement technology needs to have toenail-sized levels of precision. But it doesn't. VAR's offside decisions depend on cameras with a frame rate of 50 frames per second: that is, one every 0.02 seconds. In that time, however, a defender and an attacker might each have moved as much as 20 centimetres.

So in one sense, the critics are right: some offside decisions are too close for VAR to judge accurately. In another sense, though, those critics are wrong: measuring offside with VAR is clearly far more accurate than asking humans to measure it in real time using only their eyes. That leaves us in the strange situation where offside decisions have probably never had less error – and yet they have never been more controversial.

It is a similar story with handball, the rule that outlaws players – with the exception of goalkeepers – ever using their hands and arms to control or block the ball. Before VAR came along, the handball rule was just 20 words long: "Handling the ball involves a deliberate act of a player making contact with the ball with the hand or arm." Since VAR, it has undergone several revisions and is now 11 times as long. Referees must decide whether the hand or arm has moved towards the ball, whether the player in question has used their hand or arm to make their body unnaturally bigger, whether the handball has led to a goal or a goal-scoring opportunity and numerous other elements.

Boiling point

In both cases, that of offside and handball, what we are seeing now in football has been witnessed throughout the history of measurement: improving measurement often first involves the quantification of error, and that can sometimes seem like a step back rather than a step forward. When you start scrutinising reality at an increasingly granular level, it often turns out to be weirder and more difficult to pin down than you might think.

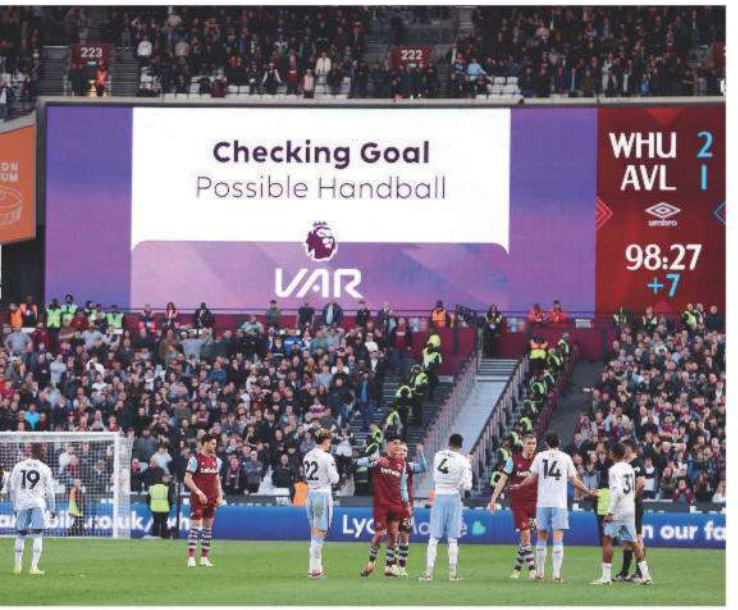
Consider the thermometer. When scientists first started to develop instruments for measuring temperature, they were frustrated by how hard it was to define boiling water. As Hasok Chang discusses in his book *Inventing Temperature*, in the 18th century, scientist Jean-André Deluc produced a detailed categorisation of the different stages of boiling water: common boiling, sifflement (hissing), soubresaut (bumping), explosion, fast evaporation only and bouillonement (bubbling). "Deluc had started his inquiry on boiling by wanting to know the temperature of true boiling," wrote Chang. "By the time he was done, he no longer knew what true boiling was." What had seemed like a simple and well-understood aspect of reality became clouded in confusion, in the same way that VAR set out to make handball decisions more accurate and ended up with no one knowing what handball was any more.

We have forgotten this in the world of the physical sciences, because the confusion over

RYAN PIERSE/GETTY IMAGES

soubresaut and sifflement are long behind us. We now have measurements for temperature, time, distance and mass that are many times more precise than most of us require when setting an alarm or weighing flour, say. Outside of the physical sciences, however, the errors and compromises involved in measurement can make you wonder if the pursuit of greater precision is ultimately worth it – and that is true not just of football but lots of other areas too.

GDP is a metric that the whole world relies on to decide if national economies are succeeding or failing. But when you dig into it, it is a bit of a mess. In his book *The Hidden Half*, Michael Blastland shows that measurements of quarterly GDP growth are often subject to several revisions in subsequent years. In the first quarter of 2012, statisticians said that the UK economy had shrunk by 0.2 per cent, for instance. Five years later, that had been revised upwards to growth of 0.7 per cent. That is the difference between likely recession and exceptional growth.



Left: players and fans await a VAR decision in the last minute of a match. Far left: lines are drawn on footage when checking for a possible offside

On-field referees are asked to check video replays if their original decision is called into question

Exams are another example: employers and universities depend on the ability of these tests to measure human achievement, yet we know that exams are beset by error and uncertainty. There are also many other fields that are trying to create new measurements for nebulous concepts. Health economists use a metric called quality-adjusted life years to estimate the benefits of a new drug. Risk managers have developed the "micromort", a unit of risk that represents a 1-in-a-million chance of death.

Many of these new measurements are like VAR's offside calls. They provide answers to important questions, and they are better than one human making a snap judgement. But they have frustrating weaknesses and limitations. In some ways, they are the victims of the stunning success of measurement in the physical sciences, because they can't provide the same degree of certainty we have come to take for granted there.

When new drugs are being trialled, people want guarantees they are safe, not probability distributions of different side effects. When students sit exams, they want to be sure they will get the grade they truly deserve, not confidence intervals that overlap the grade boundaries. When politicians write snappy tweets about how increases in GDP prove the wisdom of their policies, they don't want to add asterisks saying "subject to rolling revisions and redefinitions over the next decade".

Going back to football, could we improve our metrics and reduce their measurement error down to the levels seen in the physical sciences? For the measurement of offside, the solution is simple, if not easy: more cameras, better cameras, constant tracking of players and the ball and adding sensors to balls. Semi-automated offside systems have been trialled in big tournaments and one is due to be introduced to the Premier League soon.

The case for AI

Handballs and other fouls are a trickier problem. In my book, I propose creating a metric similar to the micromort and quality-adjusted life years: the Foul Probability Index. Here is a brief summary of how it would work: first, you would get a large group of players, managers, fans and officials to judge a series of short video clips of football incidents. You would use the results of their judgements to determine the percentage chance that each incident is a foul. You would then have a distribution of incidents and could decide where on the distribution the cutoff for a foul lies. The resulting data would be used to train an artificial intelligence, and in a live match, you would send a video clip of an incident to the AI and ask it whether or not a foul was committed.

Although you would need AI to apply such an index during a live match, the index would be constructed using human intelligence – ideally, the aggregated judgements of thousands of humans drawn from every part of the amateur and professional game. I also propose making these decisions using a psychometric technique called comparative judgement. In this context, this would mean each judge would look at two video clips of possible fouls and say which is more likely to be a foul. This is better than deciding based on a single video clip in isolation, a more common but more error-prone technique known as absolute judgement.

However, it isn't clear that fans would welcome such an approach. One striking aspect of the debate about VAR is that it has made people realise that accuracy isn't the only virtue. Speed and simplicity matter too, and are threatened by complicated and lengthy VAR checks that ruin spontaneous and joyful goal celebrations.

One school of thought says we need to stop focusing on trying to optimise the accuracy of decisions and instead focus on optimising the experience of the game as a whole. Sweden's top-flight football league has refused to introduce VAR. Perhaps others will follow.

The alternative view is that data is already taking over football, as it is taking over everything else. New metrics are invading the game. The expected goals metric – which tells you how likely it is that a shot on goal leads to an actual goal – is used extensively by team analysts and is popular with fans too. Given that, some kind of data-based upgrade of VAR seems inevitable.

I don't think VAR as we know it will be around for much longer. But will it be abandoned as a dead end while we revert to old-fashioned human refereeing, or is it a stepping stone to something better?

The answer will have significance beyond the game of football. A world in which we have a new and improved VAR is probably one where we have powerful AI-enhanced abilities to measure all kinds of nebulous concepts, and where we have made our peace with the trade-offs they require. That will have implications for all the new measures of the seemingly immeasurable that are increasingly defining our world. ▮

Daisy Christodoulou is director of education at No More Marking. Her latest book is *I Can't Stop Thinking About VAR*

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Mathematics of life

It all adds up

Fibonacci numbers offer us a neat trick for converting between units. Get ready to impress your friends, says **Katie Steckles**

Katie Steckles is a mathematician, lecturer, YouTuber and author based in Manchester, UK. She is also adviser for *New Scientist*'s puzzle column, BrainTwister. Follow her @stecks

Fibonacci numbers
1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, 377, 610… and so on!

CONVERTING between units is often something you have to do on the fly, and it is made easier when you memorise some rough equivalents. For instance, an imperial pint is 568 millilitres, but I often think of it as being about half a litre to make conversions simpler. I know a yard is a bit less than a metre, there are 2.2 pounds in a kilogram and a foot is 30 centimetres (thanks to rulers).

But maths gives us a neat trick for one unit conversion, and it is related to Fibonacci numbers: a sequence that starts with 1, followed by another 1 and then each term is the sum of the previous two. So $1 + 1 = 2$, $1 + 2 = 3$, $2 + 3 = 5$, $3 + 5 = 8$ and so on.

These numbers are named after Fibonacci, a 13th-century mathematician, but were used by Indian mathematicians in 200 BC to study rhythmic patterns in poetry. Flowers (like the sunflower, pictured) often have seeds arranged in Fibonacci numbers of spirals running in each direction, because it gives the most efficient use of space.

One way to study number sequences is to consider the ratios between successive terms. For the Fibonacci numbers, the sequence of ratios between pairs of terms – dividing the larger by the smaller – starts with $1 \div 1 = 1$, then $2 \div 1 = 2$, $3 \div 2 = 1.5$, $5 \div 3 = 1.667$, $8 \div 5 = 1.6$ and then $13 \div 8 = 1.625$. After a bumpy start, they get closer and closer to a particular value, somewhere around 1.62.

The exact value is $(1 + \sqrt{5}) \div 2$, or 1.618033988749, and is often called the Golden Ratio, or ϕ (phi). It has uses in geometry and architecture, but it is also close to another helpful ratio: 1.609344.

STUART MONK/ALAMY

If you recognise this number, you may often convert miles to kilometres. A distance of 1 mile is 1.609344 km. While this isn't exactly the Golden Ratio, it is close enough that we can use Fibonacci numbers to do a fun trick.

Since the ratio between pairs of consecutive Fibonacci numbers is getting closer and closer to somewhere near this number, if you want to convert a number of miles to kilometres, and the number of miles is a Fibonacci number, the number of kilometres will be close to the next number in the sequence. So, 5 miles is about 8 km (it is actually 8.04672 km), and 8 miles is about 13 km (it is 12.874752 km). The bigger the numbers, the more accurate the conversion will be.

It also works backwards: to convert kilometres to miles, just take the previous Fibonacci number. With a good memory (or a cheat sheet), you can make a conversion just by looking at the next or previous number in the list. And if your number of miles isn't a Fibonacci number, you can add these numbers: 15 miles is $(2 + 13)$ miles, or about $(3 + 21) =$ 24 km (actually 24.14016 km).

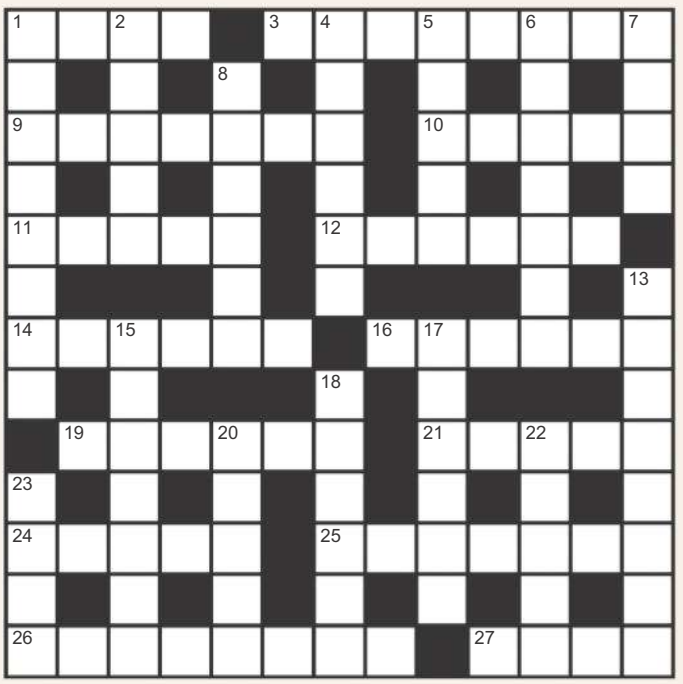
You can use this trick to impress your friends – or just enjoy a beautiful mathematical coincidence. ∎

Mathematics of life appears monthly

Next week
Debunking gardening myths

These articles are posted each week at newscientist.com/maker

Cryptic crossword #149 *Set by Trurl*



Scribble zone

Answers and the next quick crossword next week

ACROSS

1 In company with cardinals, see one with round bottom and point (4)
3 Going the wrong way, dropping an F-, naturally (2,6)
9 With Newton heading west, infinitely persistent – and gutsy? (7)
10 I'll read out passage (5)
11 Salut! Getting drunk in low joint (5)
12 Genius: being inspired is only part of it (6)
14 Half of district going after Greek character who's barely been seen? (6)
16 Trurl's loudly ready for a holiday (or a strike) (6)
19 Double drama, but no article in paper (3-3)
21 New York salad, without dressing, for African vegetarian (5)
24 Bodies is rubbish – thrown back (5)
25 Tom on top of the world? He's like Martin! (7)
26 M appears confused by routine medical procedure (3,5)
27 What's used in galvanising half of citizens to mobilise (4)

DOWN

1 Nearly making first of errors as bodybuilder's assistant (8)
2 Relating to birth in part of South Africa (5)
4 Having eaten more, one's earth might be clayey (6)
5 Yes, a pig is short, relative to a giraffe (5)
6 Disease was on the increase, with over 50 affected, in the beginning (7)
7 This clue, with no subject or level (4)
8 Forces to get broadcast awards (6)
13 LA intact, but damaged by ocean (8)
15 500 covered in powder strewn around by weather phenomenon (7)
17 Put together, possibly, what's over fireplace (6)
18 Trurl's taking a large dose of strong drug, for eye condition (6)
20 Pouring rain isn't so miserable – for starters, it might make rainbows! (5)
22 Code – like 102 (5)
23 Prevent vessels turning up (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #279
set by Bethan Ackerley

1 Tau particles have what value of spin?

2 Zoozve is a quasi-moon of which planet in the solar system?

3 Edaphology and pedology are branches of the study of what substance?

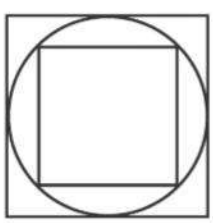
4 *Rickettsia prowazekii* is a bacterial species behind which disease?

5 Ayn Ghazal is a Neolithic site in which modern-day country?

Answers on page 47

BrainTwister
set by Katie Steckles
#47 Squares and circles

A circle is drawn so it touches the sides of a square, and then the largest square that fits is drawn inside the circle.



What is the ratio between the area of the small square and large square? (Hint: you might find it useful to rotate the inner square.)

Consider the larger square and the circle. How many copies of the circle do you need to completely cover the square?

With a nod to the late mathematician David Singmaster, who wrote a paper based on this problem: which fits better – a square peg in a round hole, or a round peg in a square hole? (By "fits better", we mean a larger proportion of the hole is taken up by the peg.)

Solution next week

Blowing up

Could a huge, prolonged volcanic eruption, like those said to have caused several past mass extinctions, happen again?

Mike Follows
Sutton Coldfield, West Midlands, UK
Yes, huge, prolonged volcanic eruptions could happen again, though there are usually warning signs. Increased seismic activity, changes in gas emissions and ground swelling often precede an eruption. These can be monitored, as can changes in thermal images taken of volcanoes.

Despite these advances, the exact timing, magnitude and nature of an eruption are difficult to predict. However, effective monitoring led to the correct prediction of the 1980 eruption of Mount St Helens in the US and the 1991 eruption of Mount Pinatubo in the Philippines, though it was bigger than expected.

Basalt flows produced by several volcanoes created the Deccan Traps in western India during the Late Cretaceous Period, around 66 million years ago, and are associated with the mass extinction that included the demise of most of the dinosaurs.

"Scientists predict a section of the Cumbre Vieja volcano will drop into the ocean, sending a tsunami across the Atlantic"

The Yellowstone supervolcano in the US is expected to erupt in the future and have a similar impact to the 1991 Mount Pinatubo eruption, which temporarily reduced global temperatures by 0.5°C. Some scientists have predicted that a large section of the Cumbre Vieja volcano on La Palma will collapse into the ocean if it erupts, sending a tsunami racing across the Atlantic to devastate the eastern seaboard of the US, which could have significant economic and political repercussions.

It is possible that, in future, volcanoes could be "defused" by cooling the magma or reducing the pressure in the system.

Earthquakes, which often accompany and can even trigger eruptions, are also tricky to predict. The manslaughter convictions of six scientists (later overturned) and a government official for failing to predict the 2009 L'Aquila earthquake in Italy caused uproar in the scientific community.

Advances in technology, such as seismometers and GPS, have improved our ability to monitor seismic activity and understand tectonic movements, which helps scientists to assess earthquake risks. Scientists can make long-term probabilistic forecasts based on the study of fault lines, historical seismic activity and geological conditions. While some patterns and precursors, like small fore-shocks or changes in groundwater levels, can occur, they aren't consistent enough to serve as reliable indicators of an imminent earthquake.

Hillary Shaw
Newport, Shropshire, UK
In short, yes. There are several supervolcanoes around the world that may erupt in the future. Yellowstone is perhaps the best known, but there are others in South America, the Mediterranean, Indonesia and the western Pacific rim.

Lakes in Yellowstone show land tilting, with submerged trees at one end and dry lake bed at the other, indicating the lava body below may be growing.

Two examples from history come to mind that showcase the devastating effects of large eruptions. Firstly, there was the Laki eruption in Iceland beginning in 1783, which caused mass casualties and also cooled the global climate. Secondly, there was the global volcanic winter of AD 536, when Procopius in Constantinople recorded the appearance of a strange, dark cloud that stayed put for months, perhaps originating from massive eruptions partway around the globe in North America, causing global cooling and crop failures.

Similar effects to these could also be produced without a massive volcanic eruption, for example if a large asteroid hit Earth. There would be a global drop in temperature, there might also be acid rain from the sulphur ejected, as well as crop failures, starvation and extinctions. And the species that produced this magazine may well be among those that go extinct.

CATHERINE FALLS COMMERCIAL/GETTY IMAGES

Is there a reason we only use 12 notes in a Western chromatic scale?

This week's new questions

Scaling it up **Why do we only use 12 notes in Western music?**
John Grant*, Caloundra, Queensland, Australia*

Building blocks **All life on earth is based on DNA. If we ever find life on other worlds, are there viable alternatives for coding for life that it may be based on?**
Mike Egan*, Meath, Ireland*

Red or blue pill

Is there any scientific evidence disproving the notion we are part of a vast simulation run by an advanced civilisation? (continued)

Rob Walter
Via email
Some previous answers offering evidence for the notion we aren't living in a vast simulation relied heavily on the word "vast".

The complexity of our universe suggests we aren't in a simulation run by an agent in a three-dimensional universe with laws of physics similar to our own. Or, viewed another way, it is evidence we will never simulate a universe of similar complexity to our own.

But what if the simulation containing our universe isn't vast compared with the 19-dimensional,

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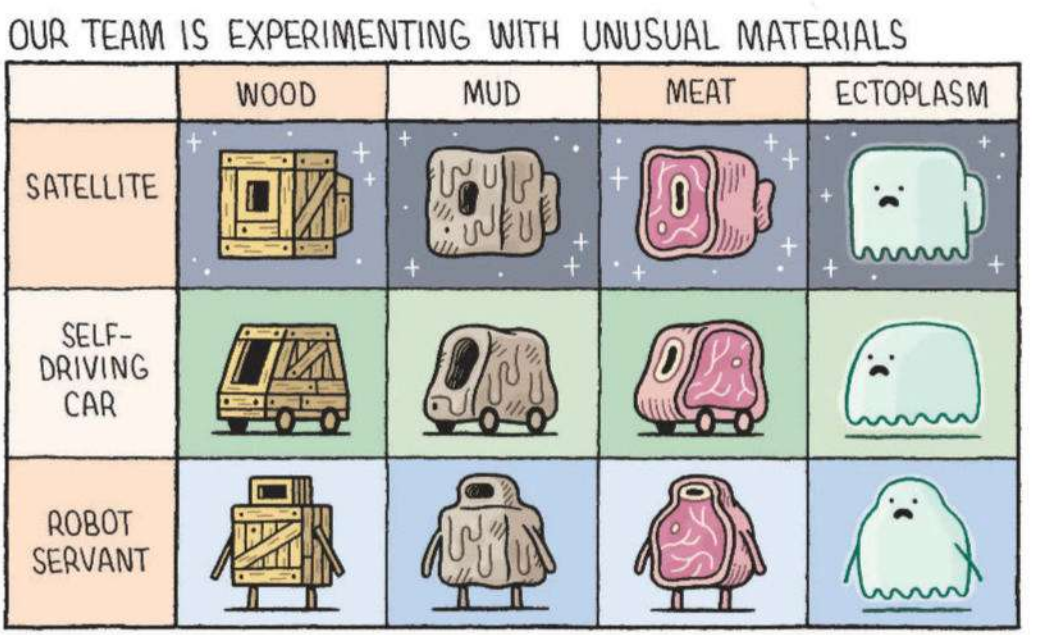


physically exotic reality it is being run in? What if it requires the technological equivalent of a smartphone to run in this far more information-dense world?

The question of whether we live in a simulation is practically equivalent to the question of whether God exists. People have been looking for evidence against God's existence for a long time without success, because proving non-existence is famously difficult. Using the definition that religion is a system of beliefs involving special hats, I would say it is probably more fun to believe in God than a simulation, but simpler to believe in neither.

Paul O'Toole
Greasby, Merseyside, UK

Your correspondent argues against the idea that we are living in a simulation because of the unfeasibly immense computational power it would demand. However, suppose "reality" – especially its fine detail – was only properly rendered when it was being observed. The rest of the time, the simulated universe could exist as a vague cloud of probabilities – much less computer power required. But wouldn't it look odd to those simulated scientists trying to make sense of it all.

"People have been looking for evidence against God for a long time without success, because proving non-existence is difficult"

David Bortin
Whittier, California, US

What do you mean "we"? Suppose that we (or you, at least) are merely "part of a vast simulation run by an advanced civilisation". In that case, any evidence to which you might have access would be just an attribute of the simulation and, as such, could neither prove nor disprove anything about the greater civilisation.

Ergo, such disproving evidence cannot exist in your reality, and the supposition cannot be disproven. Hence, the answer to your question is an unequivocal "no!".

Cosy spot

Why do cats like to sit on newspapers and magazines? (continued)

Frank McLoughlin
Newcastle upon Tyne, UK

In the late 1950s, we had three relevant items: a very choosy cat, a Marconi CR100 radio – in appearance like a 12-inch metal cube with dials and knobs on the front – and newspapers.

When our father had finished reading the papers, a discarded one would be left on top of the radio, which was placed on the sideboard in our kitchen. The cat liked to sit in regal state on top of the radio enjoying the heat generated by the thermionic devices within. However, he would only do this if a certain high-quality newspaper was in place, spurning newspapers of a lower standard. ▮

Answers

Quick quiz #279 *Answers*

1 1/2
2 Venus
3 Soil
4 Typhus, more specifically epidemic typhus
5 Jordan

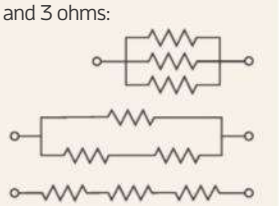
Quick crossword #171 *Answers*

ACROSS 1 Yttrium, **5** Short, **8** Abalone, **9** Union, **10** Tesla, **11** Labiate, **12** Hoover, **14** IQ test, **17** Saguaro, **19** Click, **22** Tuned, **23** Audubon, **24** Gecko, **25** Tessera

DOWN 1 Yeast, **2** Teams, **3** Iron Age, **4** Muesli, **5** Squib, **6** Oxidate, **7** Tiniest, **12** Hashtag, **13** Organic, **15** QR codes, **16** Cobalt, **18** Audio, **20** Imbue, **21** Kenya

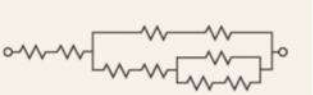
#46 OhmWork *Solution*

These are the three other possible circuits using three 1-ohm resistors. Their overall resistances are 1/3, 2/3 and 3 ohms:



The circuit described, made of 10 1-ohm resistors, has a resistance of 22/7 ohms (approximately π).

The unique (except for equivalent rearrangements) circuit achieving 22/7 ohms with nine 1-ohm resistors looks like this:



Revenge on referees

Our news colleagues Jacob Aron and Michael Le Page have drawn Feedback's attention to a post on social media site BlueSky, which highlighted a scientific paper in awed tones.

The study in question was recently published in the *International Journal of Hydrogen Energy*. There are seven authors. It is about the ways hydrogen atoms can infiltrate certain metal alloys and make them brittle. It focuses on calculating exactly where the hydrogen atoms place themselves in the crystal structure of the metal, in order to understand the mechanism of this embrittlement.

At this point, you may be wondering what this piece of research is doing in Feedback. Well, the introduction concludes with the following paragraph: "As strongly requested by the reviewers, here we cite some references [[35], [36], [37], [38], [39], [40], [41], [42], [43], [44], [45], [46], [47]] although they are completely irrelevant to the present work."

For anyone who hasn't worked in academia, the best way we can explain this is that the authors are being gloriously petty. Their article has been examined by anonymous peer reviewers, who (among other suggestions) have urged them to cite the 13 older studies in the list. The authors, left with no choice but to insert the supposedly irrelevant studies, have refused to incorporate them into their actual text, but instead included them while simultaneously drawing attention to their irrelevance.

Or, as BlueSky user @Dave nλ=2dsinθ:protein: put it: "Absolute shots fired". By the way, kudos to @Dave nλ=2dsinθ:protein: for having a username that pushed *New Scientist*'s font to its limits and sent Feedback to a search engine. The little equation in the middle is, we discovered, Bragg's law, which describes how crystal lattices scatter incoming waves.

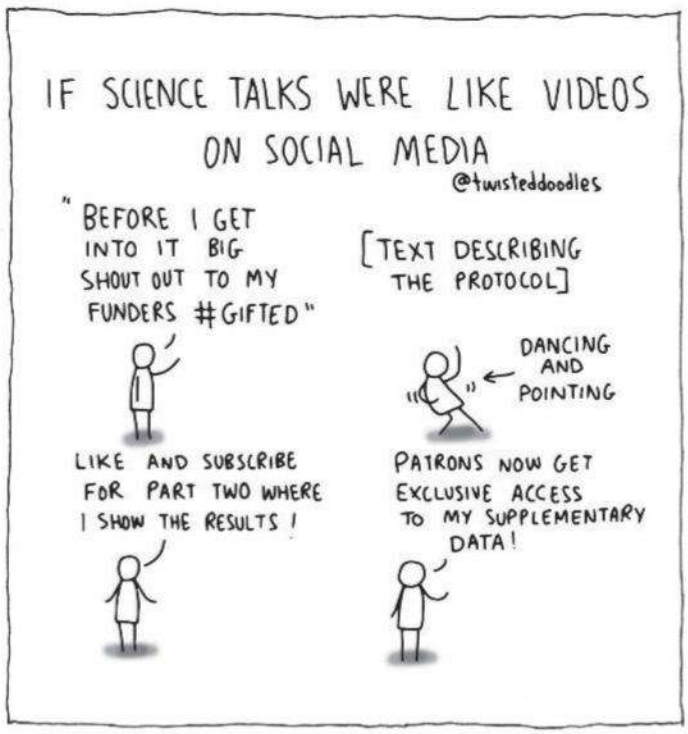
Anyway, once Feedback had stopped having flashbacks to our brief time in academia, in which this kind of thing happened to us but we didn't have the nerve to kick back in print, we did our due diligence and looked up all 13 references.

All are concerned with alloys and other composite materials, but none of them seems to be about hydrogen embrittlement. Most are so technical that Feedback was rather defeated in our attempt to fully comprehend them: any readers more familiar with composite materials are welcome to weigh in at the usual address. Still, even with our poor understanding, none of the references seems directly relevant.

However, Feedback did notice something curious. Again and again, the same authors appear in the 13 studies' author lists – and one author was involved in all of them.

Feedback doesn't want to put on a tinfoil hat, especially if it has been embrittled by hydrogen. But we wonder if we might have identified the anonymous peer reviewer. Our question now is: how did this get into print? Did the editors not notice the prank – or did they allow it for reasons of their own? Enquiring minds want to know.

Twisteddoodles *for New Scientist*


IF SCIENCE TALKS WERE LIKE VIDEOS ON SOCIAL MEDIA
@twisteddoodles
"BEFORE I GET INTO IT BIG SHOUT OUT TO MY FUNDERS #GIFTED"
[TEXT DESCRIBING THE PROTOCOL]
DANCING AND POINTING
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A fishy tale

Speaking of taking ideas from colleagues, assistant news editor Sam Wong flagged an intriguing study in *Water Resources Research*. This journal is not, we confess, one of Feedback's daily reads, but we seem to have been missing out.

The study is about the biblical miracle of loaves and fishes, in which Jesus apparently fed 5000 people using five loaves and two fish. The authors propose a naturalistic explanation: a seiche or standing wave. The idea is that waves blowing over a lake sometimes create a standing wave, causing deep water to rise to the surface. In Lake Kinneret, the Sea of Galilee from the Bible, this deep water is low in oxygen – so if it rises to the surface, it can cause fish to asphyxiate en masse.

The authors document two such events in Lake Kinneret in 2012. They also note that they seem to be quite rare: there hasn't been one since 2012. That means most people may not have been aware of the possibility, especially if they had travelled to listen to a charismatic speaker and lacked local knowledge.

Feedback is adding this to the long list of scientific explanations for apparent supernatural events, like the manna from heaven being crystallised honeydew from scale insects and the tendency of infrasound to cause spooky sensations that can be interpreted as hauntings. We have also removed our tinfoil hat, as we worry it might act as a conductor for a divine lightning bolt.

Moon of Uranus

News reaches us from the front of this issue that Voyager 2's visit to Uranus in 1986 came when the planet wasn't its usual self, thanks to a gust of solar wind. As a result, many of our ideas about Uranus will have to be rethought – and some believe it is even possible there is life on one or more of its moons.

Life on Uranus, you say? Actually, life on Uranus's moon? We hope it isn't Klingons. Or as writer Tess Stenson put it: NASA, "get your ass to Uranus".

Feedback spent more time than we should trying to think of puns, but our slate has been wiped clean. Some bright spark, conscious of jokes about the planet's name, decided to name all Uranus's moons after Shakespeare characters, choosing respectable names like Rosalind and Oberon. This does mean we can rule out life on one of the moons: Juliet is definitely lifeless, there was a play about it. Meanwhile, astronomers urgently need to find some more satellites so Uranus can be orbited by Bottom.

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